

TABLE 6

CAPTIVE/MERCHANT SHIPMENTS FOR ALUMINUM FLUORIDE

<u>Year</u>	<u>Total Shipments</u> (Thousand Tons)	<u>Merchant Shipments</u> (Thousand Tons)	<u>Approximate Captive Shipments</u> (% of Total)
1968	138.3	61.6	54.5
1969	143.0	53.8	62.4
1970	134.6	52.3	61.1
1971	155.7	65.1	58.2
1972	136.5	49.8	63.6

SOURCE: U.S. Department of Commerce.

in 1972 captive shipments of aluminum fluoride represented approximately 64% of total shipments. Alcoa and Kaiser are the two major factors in captive consumption of aluminum fluoride. Reynolds has closed its aluminum fluoride plant at Bauxite, Arkansas, and is believed to be supplied primarily by Allied Chemical.

### 3. Supply Characterization

#### a. Manufacturing Routes

Aluminum fluoride is manufactured from hydrofluoric acid and alumina hydrate. The alumina hydrate used is an intermediate product obtained in the processing of bauxite to alumina. It is necessary to use the hydrate for reaction because the alumina prepared for electrolysis and calcined at high temperatures is not reactive. Newer facilities use a fluid bed system for the reaction between hydrofluoric acid and the alumina hydrate.

Alcoa has been operating a plant in Fort Mead, Florida, since late 1971 to produce aluminum fluoride from fluosilicic acid, a by-product of phosphoric acid manufacture. It is anticipated, however, that for the foreseeable future the fluosilicic acid route to aluminum fluoride will constitute only a relatively minor part of total production, with most of the output continuing to be derived from hydrofluoric acid and hydrated alumina.

#### b. Producers

At the present time there are four manufacturers of aluminum fluoride operating six plants. Their plant locations and estimated capacities are shown in Table 7. Two of the three major primary aluminum producers are included in the list. As previously indicated, Reynolds, the second largest aluminum producer (in terms of U.S. aluminum ingot capacity) has shut down its aluminum fluoride facility. In addition, Olin also had an aluminum fluoride plant in Joliet, Illinois, which has been shut down.

Both Alcoa and Kaiser in addition to supplying their own captive requirements for aluminum fluoride also supply the aluminum fluoride requirements of some of the smaller, non-integrated aluminum producers, such as Intalco, Ormet, Anaconda, and Harvey. Allied and Stauffer are primarily merchant suppliers of aluminum fluoride.

All of the aluminum fluoride producers are substantially integrated to raw materials, and, in the case of Alcoa and Kaiser, to downstream products, i.e., primary aluminum. More specifically, Alcoa, Kaiser, and Allied produce both hydrofluoric acid and alumina hydrate in addition to aluminum fluoride. Stauffer produces hydrofluoric acid and aluminum fluoride, but not alumina hydrate.

## B. PLANT SHUTDOWN FACTORS

If treatment costs cannot be passed on as price increases, the simplistic model says that the producer either absorbs them or shuts down his plant. The shutdown decision will involve both economic and strategic (i.e., noneconomic) considerations as follows.

Profitability--The after-tax cost per ton of water treatment compared with unit after-tax net income measures the producer's ability or willingness to absorb the added cost.

Cash Flow--Plants will continue to operate temporarily at essentially zero profitability (if necessary) if the plant is producing a positive cash flow (and has a competitive process and is in a stable or growing market).

Ratio of Investment in Treatment Facilities to Net Fixed Investment--If the new investment in water treatment facilities bulks large in comparison with existing plant investment (and other factors are marginal), a shutdown decision may be in order. In some instances, the availability (and cost) of capital to the producer may influence the shutdown decision.

Integration--The degree of backward or forward integration is a factor in the shutdown decision. A producer (or industry) with a significant raw material position or one using the product for downstream manufacture is less likely to curtail production than a non-integrated producer (or industry).

Chemical Complex--An isolated plant would be unable to take advantage of common treatment facilities.

Other Environmental Problems--If a plant has already committed funds for air pollution, it will be more likely to commit the additional funds necessary for water pollution. Alternately, if a company faces both water and air pollution abatement (and/or unusual OSHA) costs, the magnitude of the environmental and safety costs taken together may prompt a plant closing whereas any one taken alone would not.

Emotional Commitment--The emotional commitment of the company to that particular product (taking into account protection of competitive position, prestige, the importance of the product in the company's long-range strategy, etc.) may be a factor in the shutdown decision.

Ownership--Other things being equal (and negative), multi-industry companies are more likely to shut down marginal plants than less-diversified producers. The premise is that the multi-industry producer has other (and better) investment opportunities than the single product company (particularly a privately-held, family business).





#### IV. INDUSTRY CHARACTERIZATION

##### A. ALUMINUM FLUORIDE

###### 1. Summary

In 1972, U.S. consumption of aluminum fluoride totaled 151,000 tons of which 139,000 tons were derived from domestic production and 12,000 tons were supplied by imports. U.S. output of aluminum fluoride, which is used almost entirely in the production of primary aluminum, has increased at an average annual compound rate of approximately 7% for the period 1963 through 1972. In its use as a fluxing agent for primary aluminum production, aluminum fluoride is to a minor extent interchangeable with another fluxing agent, cryolite. In general, however, there are no direct substitutes for aluminum fluoride in this major application. A very substantial part of aluminum fluoride consumption is captively supplied, viz. 64% in 1972.

There are currently four U.S. producers of aluminum fluoride, two of which--Aluminum Company of America and Kaiser Aluminum & Chemical--are also major aluminum producers. The two remaining aluminum fluoride producers, not integrated forward to aluminum production, are Allied Chemical and Stauffer Chemical. Productive capacity for aluminum fluoride has been in excess of actual production in recent years. In 1972 the industry operating rate was approximately 78%.

###### 2. Market Characterization

###### a. Market Size and Growth

Department of Commerce data for aluminum fluoride production, foreign trade, and apparent consumption for the period 1963 to 1972 are shown in Table 4. During this time span U.S. production of aluminum fluoride has increased at an average annual compound rate of approximately 7.0% (assuming 1972 production was somewhat below the long-term trend line). If the estimated 12,000 tons of imported aluminum fluoride is added to the 138,800 tons of 1972 production, the apparent U.S. market for the material was somewhat over 150,000 tons. (The exact quantity of aluminum fluoride imports cannot be determined because the material is grouped with a number of other aluminum compounds in U.S. Tariff Commission import data.)

TABLE 4

PRODUCTION, FOREIGN TRADE, AND APPARENT CONSUMPTION  
OF ALUMINUM FLUORIDE

(Thousands of Tons)

<u>Year</u>	<u>Production</u>	<u>Imports</u>	<u>Exports</u>	<u>Apparent Consumption</u>
1963	81.4	NA	NA	NA
1964	92.6	NA	NA	NA
1965	111.9	NA	NA	NA
1966	124.8	NA	NA	NA
1967	131.6	NA	NA	NA
1968	139.0	NA	NA	NA
1969	143.1	NA	NA	NA
1970	135.7	NA	NA	NA
1971	157.9	NA	NA	NA
1972	138.8	12.0	NA	150.8

SOURCE: U.S. Department of Commerce.

#### b. Uses

Aside from minor applications in secondary aluminum production and use as a metallurgical and ceramic flux, aluminum fluoride is used entirely by producers of primary aluminum. In primary aluminum production, aluminum fluoride functions as a major make-up ingredient in the fused electrolyte of the aluminum reduction cell. Although there is no actual consumption of the aluminum fluoride in the electrolysis reaction, there are mechanical losses, pyrohydrolysis and some carbon tetrafluoride formation. Consumption varies between companies and smelters but averages between 60 to 70 pounds of aluminum fluoride per ton of aluminum produced. In addition to operating requirements (pot make-up), additional quantities of aluminum fluoride are needed for pot line start-up. A 65,000 ton pot line, for example, would require approximately 600 tons of aluminum fluoride as an initial charge.

The consumption of aluminum fluoride per ton of primary aluminum produced has declined in recent years as a result of the industry's efforts to realize more efficient recovery of fluorine values from pot linings and flue gases. Table 5 presents estimated consumption of aluminum fluoride in the U.S.

As previously mentioned, aluminum fluoride is also used in the refining of secondary aluminum. The two accepted techniques for producing secondary aluminum are referred to as "wet fluxing" and "hot fluxing." Aluminum fluoride is used in both wet and hot fluxing techniques to remove magnesium from the molten scrap, the actual quantity depending on the magnesium content of the scrap. Aluminum fluoride is also used in brazing fluxes (for aluminum fabrication), fluxes for ceramic glazes and enamels, and for welding rod coatings.

#### c. Substitute Products

In addition to aluminum fluoride, cryolite is also used as the molten electrolyte in the electrolytic reduction of alumina to aluminum metal. The two fluxes are to some degree interchangeable, depending upon operating practices and the sodium oxide content of the alumina used in the reduction plant. For start-up of a new pot line, considerably more cryolite is required (approximately 2,000 tons for a 65,000 ton pot line) than aluminum fluoride. During pot line operation, loss of fluorine values is greater than loss of sodium values. Consequently, during normal operation of a pot line, more aluminum fluoride than cryolite is used to maintain a constant composition of the melt. The effect of the industry's efforts to recover fluorine values from flue gases and pot linings will in general be more pronounced for cryolite than for aluminum fluoride.

#### d. Captive Requirements

Commerce Department data for the period 1968 through 1972 broken down by captive/merchant shipments are shown in Table 6. As indicated,

TABLE 5

U.S. CONSUMPTION OF ALUMINUM FLUORIDE

(Thousands of Tons)

	<u>Primary Aluminum Production</u>	<u>Aluminum Fluoride Consumption</u>		
		<u>Primary Aluminum</u>	<u>Other</u>	<u>Total</u>
1963	2,313	104	4	108
1965	2,755	111	4	115
1970	3,976	139	5	144
1972	4,122	144	6	150

SOURCE: Contractor estimates.

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### 3. Supply Characterization

#### a. Manufacturing Routes

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TABLE 7

ALUMINUM FLUORIDE PRODUCERS

Company	Location	Capacity	
		(Thousand Tons)	(% of Total)
Allied Chemical Corp. Industrial Chemicals Div. Specialty Chemicals Div.	Geismar, La. Marcus Hook, Pa.	38.6	21.9
Aluminum Corp. of America	Fort Meade, Fla. Point Comfort, Tex.	66.2	37.5
Kaiser Aluminum & Chemical Corp.	Gramercy, La.	55.1	31.2
Stauffer Chemical Co.	Greens Bayou, Tex.	16.5	9.4
Total		176.4	100.0

SOURCE: Published estimates.

### c. Manufacturing Economics

Estimated manufacturing costs for aluminum fluoride are shown in Table 8. The cost estimates are based on a plant with an annual capacity of 33,000 tons and a fixed investment of \$2.4 million.

As shown, the raw material component represents a very large proportion of the total cost of manufacture of \$253.25 per ton. The unit value for alumina hydrate used in the calculation is based on Commerce Department industry data for 1972. For that year, the unit value of total alumina hydrate shipments was \$65.11 per ton. Commercial (i.e., merchant) shipments had a unit value of \$78.56 per ton. By difference, therefore, the unit value of interplant shipments (based on the quantities and dollar values of total shipments minus commercial shipments) was \$60.56 per ton. Assuming an average cost of approximately \$2.50 per ton for freight, we have used \$63.00 per ton in the calculation.

Unfortunately, Commerce Department data on the unit value for commercial shipments (and therefore for interplant shipments) of hydrofluoric acid are not available. In 1972, the unit value for total shipments of aqueous hydrofluoric acid was \$317.76 per ton. We have assumed a manufacturing cost for hydrofluoric acid of \$225 per ton and have used that in our calculations for aluminum fluoride manufacturing costs. The implication is that anyone making aluminum fluoride must be integrated to hydrofluoric acid. Interestingly, Reynolds, not integrated to hydrofluoric acid, has closed its aluminum fluoride facility.

### 4. Supply/Demand Balance

U.S. aluminum fluoride capacity is in excess of actual production and has been for the past several years, even with the closing of aluminum fluoride facilities by Reynolds and Olin. Presumably, Reynolds found it more economic to purchase aluminum fluoride, while low profitability and the small merchant market may have prompted Olin's decision to close its plant. For 1971 and 1972, production represented 89.5% and 78.5% of current capacity of 176,400 tons.

### 5. Prices

In Table 9 we have shown list versus actual prices for aluminum fluoride for the period 1963 through 1972. The "actual" prices are as calculated from Commerce Department data for total shipments and represent industry average plant prices. In 1972 plant prices returned very nearly to levels which prevailed during the early 1960's. Throughout the period illustrated, however, plant prices were considerably below list prices.

## B. BARIUM CARBONATE

### 1. Summary

U.S. production of barium carbonate reached a maximum level in 1966 totaling almost 95,000 tons per year. Production has been declining since



TABLE 8

ESTIMATED MANUFACTURING COST, ALUMINUM FLUORIDE

Plant Capacity	33,000 Tons/Year
Fixed Investment	\$2,400,000

<u>Item</u>	<u>Units</u>	<u>\$/Unit</u>	<u>Units/Ton</u>	<u>\$/Ton</u>
Raw Materials				
Hydrofluoric Acid	Ton	225.00	0.67	170.85
Alumina Hydrate	Ton	63.00	0.98	61.74
Utilities				
Power	Kwh	0.015	143.00	2.15
Fuel	MM Btu	0.70	2.25	1.58
Direct Labor				
Supervisors				4.30
Operators				
Overhead (100% direct labor)				4.30
Maintenance (50% direct labor)				2.15
Maintenance Supplies (5% investment/year)				3.63
Depreciation (2% investment/year)				1.45
Taxes and Insurance (1½% investment/year)				1.10
Total				\$253.25

SOURCE: Contractor estimates.

TABLE 9

ACTUAL VERSUS LIST PRICES FOR ALUMINUM FLUORIDE

<u>Year</u>	<u>Shipment Quantity</u> (Thousand Tons)	<u>Value</u> (\$ Millions)	<u>Unit Value</u> (\$/Ton)	<u>List Price</u> (\$/Ton)
1963	81.1	22.18	273.49	325
1964	93.6	25.31	270.41	325
1965	110.9	26.98	243.28	325
1966	125.5	29.67	236.41	290
1967	131.5	30.86	234.68	270
1968	138.3	26.75	193.42	270
1969	143.0	28.16	196.92	290
1970	134.6	26.80	199.11	260
1971	155.7	36.74	235.97	335
1972	136.5	36.05	264.08	350

SOURCE: U.S. Department of Commerce and Chemical Marketing Reporter.



1966 as a result of the high occurrence of substitute products. Reduced market demand was one of the major factors that caused the shutdown of two plants in 1971, one of which accounted for 50% of total industry capacity. In 1972, production fell to 44,600 tons, causing a very tight supply situation. Since 1972 capacity has been increased slowly and cautiously by the three remaining producers. Production has declined at an average annual rate of 11% from 1966 to 1972.

Barium carbonate has a number of end uses; television glass and scumming prevention in brick and clay products are the most important. In these applications, barium carbonate faces the competition of substitute products, such as strontium carbonate in TV glass, and irregular surface bricks that do not require major scumming prevention. Its future market growth is expected to be static or at very best follow the growth rate of the U.S. economy.

There are currently three U.S. producers of barium carbonate, one having about half of total capacity. Because of the short supply situation and the low probability of any new company entering the market, these companies are in good control of the supply and price situation. Barium carbonate list prices have increased over 10% from 1972 to January 1974. Industry reports actual price increases up to 30% for the same period. Prices vary according to grade, volume and producer.

## 2. Market Characterization

### a. Market Size and Growth

Department of Commerce and Bureau of Mines data for barium carbonate production and imports, for the period 1963 to 1972, are shown in Table 10. Exports of barium carbonate had been negligible, if any, since U.S. market prices had been considerably higher than world prices. Thus, apparent consumption combines production and import volumes. Production of barium carbonate reached its maximum volume in 1966 with almost 95,000 tons, having shown an average yearly compound growth of 6% from 1963 to 1966. Production volume has been declining since 1966. Reduced market demand dropped production to about 60,000 tons in 1970 and 1971. This prompted the closing of two manufacturing plants, which further reduced production in 1972 to 44,600 tons. Production has been declining at an average rate of 11% a year between 1966 and 1972.

Around 1969 the television industry replaced barium carbonate with strontium carbonate for the manufacturing of faceplate glass. This caused the drastic drop in production level of about 20,000 tons from 1969 to 1970, leaving the industry, which at that time had about 100,000 tons per year capacity, with very low capacity utilization. Some plants converted part of their barium carbonate operation to strontium carbonate. Others chose to close down. Capacity conversion and plant closedown left the industry with insufficient capacity to meet demand. To establish a new supply/demand balance, the plants that remained in operation have been increasing capacity, mostly by debottlenecking their operation.

TABLE 10

PRODUCTION, FOREIGN TRADE\* AND APPARENT CONSUMPTION  
OF BARIUM CARBONATE  
 (Thousands of Tons)

<u>Year</u>	<u>Production</u>	<u>Imports</u>	<u>Apparent Consumption</u>
1963	78.9	0.8	79.7
1964	81.0	1.0	82.0
1965	85.2	0.8	86.0
1966	94.4	1.1	95.5
1967	82.2	0.8	83.0
1968	83.3	0.7	84.0
1969	79.0	0.9	81.8
1970	61.5	1.4	62.9
1971	60.5	1.1	61.6
1972	44.6**	8.3	52.9

\*Exports are negligible.

\*\*Bureau of Mines.

SOURCE: U.S. Department of Commerce.

Current demand for barium carbonate is strong and the product is in short supply because of insufficient capacity. Its end uses, however, are well defined, new applications are not foreseen, and there are a number of competitive products for its different applications. It is believed that market demand is static at approximately 55,000 tons. At best, its growth rate will follow that of the national economy since demand for barium carbonate is intertwined with consumer purchases, due to the fact that its end uses are mostly consumer products.

Until 1971 imports have been small, on the order of 1,000 tons or about 1% of production. In 1972 imports rose dramatically to 8,300 tons or about 19% of production. At present imports are estimated to account for 19 to 20% of U.S. consumption. They are not expected to maintain such levels after domestic capacity readjusts to market demand.

#### b. Uses

Barium carbonate has a variety of end uses as shown in Table 11. The glass industry is the largest single end user with about 32% of total production. Its major application is in television glass but it is also used in reflective glass beads, highway striping, laboratory glassware, decorative glass and fiberglass.

About 20% of total carbonate consumption is in brick and clay products to prevent scumming; that is, to prevent sulfate salts in the brick from working their way to the surface and giving it a dusty or frosted appearance.

Other applications are in brine treatment, frit, photographic paper and the manufacture of barium ferrites, which are employed in permanent magnets for automobile motors. These end uses combined account for 37% of total production. The remaining 11% goes into miscellaneous applications.

The use of barium carbonate as a chemical intermediate for the production of other barium chemicals has almost disappeared. This application, which until recently was believed to account for almost 40% of total output, currently requires only a very small percentage of total production.

#### c. Substitute Products

Substitute products have been the major cause in the decline of market demand and plant closings. A decrease in barium carbonate consumption for color television is directly attributable to the inroads made by strontium carbonate. Strontium has the advantage over barium of reducing the radiation which emanates from color sets. It is assumed that at this point all the conversions from barium to strontium have been made and no further drop in demand from TV tube manufacturers is expected.

In the construction industry the competitive products are bricks with irregular surfaces instead of clear-faced bricks. The use of rough-faced bricks reduces the need for the prevention of scumming and therefore



TABLE 11

BARIUM CARBONATE  
CONSUMPTION BY END USES -- 1972

<u>End Uses</u>	<u>% of Total</u>	<u>Thousands of Tons</u>
Glass	32	16.320
Brick & Clay	20	10.200
Brine Treatment	15	7.650
Porcelain Enamel Frit	10	5.100
Ferrites	7	3.570
Photographic Paper	5	2.550
Miscellaneous	<u>11</u>	<u>5.610</u>
Total	100	51.000

SOURCE: Industry estimates.

the need for barium carbonate. Currently, there seems to be in the construction industry a trend back toward the use of clear-faced bricks.

Barium ferrites used in auto magnets are threatened by strontium carbonate-based ferrites, which are said to resist demagnetization more intensely than barium ferrites. Organic polymers, such as low density polyethylene, are competing with barium carbonate in photographic paper.

#### d. Captive Requirement

Barium carbonate has been used captively in the production of other barium chemicals. Department of Commerce data, shown in Table 12, indicates that an average of 25% of total production was captively used until 1971. In 1972 the market shortage of barium carbonate, coupled with a decline in the U.S. demand for barium oxide and barium monohydrate, reduced captive consumption in favor of the merchant market. It is believed that at present barium carbonate is not used captively.

### 3. Supply Characterization

#### a. Manufacturing Routes

Barium carbonate is produced from barite ore. The ore is reduced to barium sulfide with coke or coal and the reduced mass, called black ash, is leached with water to yield an impure solution of barium sulfide. The solution is filtered and the filtrate treated with carbon dioxide or soda ash to form the barium carbonate as a precipitate. The product is then separated from the liquor, washed and dried. When carbon dioxide is used the resulting by-product requiring disposal is hydrogen sulfide. In the soda ash process, sodium sulfide must be disposed of.

#### b. Producers

In 1971 there were five producers of barium carbonate. At present only three remain, operating three facilities as shown in Table 13. In January 1972, PPG Industries closed down their 50,000 ton plant at New Martinsville, West Virginia, because of the industry's economic problems caused by a drastic reduction in demand and the environmental considerations of air and water pollution problems. The facility has not been dismantled but it is unlikely it will be brought back on-stream. Chicago Copper & Chemical Company closed an 8,000 ton plant at Blue Island, Illinois in early 1971 and had dismantled the unit.

The three companies that remain had to rapidly adjust capacity to meet the shortage caused by the closedown of half of total U.S. capacity. Sherwin Williams has been expanding its Kansas plant and is now probably at 15,500 tons capacity. FMC has also been expanding and industry sources estimate the expansion at 8,000 tons (bringing its total to 32,000 tons). These expansions will bring total capacity to about 63,000 tons per year. Any further increase in current capacity will come slowly



TABLE 12

CAPTIVE/MERCHANT SHIPMENTS FOR BARIUM CARBONATE

<u>Year</u>	<u>Total Shipments</u> (Thousand Tons)	<u>Merchant Shipments</u> (Thousand Tons)	<u>Approximate Captive Shipments</u> (% of Total)
1966	94.4	66.9	29
1967	82.2	59.6	27
1968	83.3	63.7	24
1969	79.0	59.7	24
1970	61.5	44.0	29
1971	60.5	47.2	22
1972	44.6*	NA	NA

\*Bureau of Mines.

SOURCE: U.S. Department of Commerce.

TABLE 13

BARIUM CARBONATE PRODUCERS

<u>Company</u>	<u>Location</u>	<u>1973 Capacity</u> <u>(Thousand Tons) (% of Total)</u>	
Chemical Products Company	Cartersville, Georgia	15.5	31
FMC	Modesto, California	24.0	48
Sherwin Williams	Coffeyville, Kansas	10.5	21
Total		50.0	100

SOURCE: Contractor estimates.

and from these three manufacturers. The absence of potential market growth should discourage major expansions or new plant construction by new firms.

Barium carbonate producers are diversified to the manufacture of other chemicals including strontium carbonate. When strontium carbonate began taking over the barium carbonate market for TV faceplate glass, most producers chose to convert part of their operation since they have similar processes and the same equipment can be used.

#### c. Manufacturing Economics

Estimated manufacturing costs for barium carbonate are shown in Table 14.

#### 4. Supply/Demand Balance

##### a. Capacity Utilization

In early 1973 barium carbonate plants were working at capacity to meet market demand which was higher than available capacity as a result of plant shutdowns. Manufacturers are increasing available capacity but this increase is slow and cautious as a result of an already well-defined market demand. Thus, it is expected that manufacturers will increase capacity only to the point of optimum utilization. For 1972 production is reported at essentially the same level as available capacity.

#### 5. Prices

As shown in Table 15, list prices of barium carbonate have risen steadily from \$111.50 per ton in 1965 to \$150.00 per ton in 1972. Prices vary according to grade, producers and methods of shipment. "Actual" prices, calculated from Commerce Department data for total shipments, represent industry average plant prices and they are, in most instances, only slightly below list prices. Currently, because of tightness in supply, prices are high and holding firm.

### C. BORIC ACID

#### 1. Summary

U.S. production of boric acid in 1972 was at a level of 121,400 tons. Of this, nearly 23% or 27,700 tons were exported; imports were negligible. Production has varied over the last ten years; the overall growth trend has averaged a slight 1.5% increase on a compound basis for the period 1963 to 1972; however, the 1972 level of production was just about equal to that of 1964. Growth has been hindered recently by competition from anhydrous boric acid, which U.S. Borax started producing in 1967. In the seventies growth has been stunted by supply shortages in the industry.

TABLE 14

ESTIMATED COST OF MANUFACTURING BARIUM CARBONATE (Via Carbon Dioxide Route)

Physical Investment		\$1.55 Million	
Capacity		15,000 Tons/Year	
Operating Factor		3 Shifts/SD, 330 SD/Year	
	<u>Quantity/Ton</u>	<u>\$/Unit</u>	<u>\$/Ton</u>
<u>Variable Costs</u>			
Raw Materials			
Barite Ore (at mine)	1.7 Tons	17.00	28.90
Coal (carbothermic reduction)	0.35 Tons	10.00	3.50
Utilities			
Power	400 Kwh	0.0137	5.48
Fuel			
Coal	15 MM Btu	0.50	7.50
Natural Gas	1.3 MM Btu	0.597	0.78
Process Water	0.3 M Gallons	0.40	0.12
Total Variable Costs			46.28
<u>Semi-Variable Costs</u>			
Operating Labor	3.33 Men/Shift	\$4.31/M-H	8.38
Supervision	1 Supervisor	\$15,000/Yr	1.00
Maintenance	5% of Investment/Year		5.17
Labor Overhead	60% of Labor & Supervision		5.63
Total Semi-Variable Costs			20.18
<u>Fixed Costs</u>			
Plant Overhead	40% of Labor and Supervision		3.75
Depreciation	11.1% of Investment/Year		11.47
Taxes & Insurance	1.5% of Investment/Year		1.55
Total Fixed Costs			16.77
Total Cost of Manufacture (without ore transportation cost)			83.23
Barite Ore Transportation Cost From West Coast Mine to East Coast Manufacturer (@ \$30/Ton Barite)			51.00
TOTAL COST OF MANUFACTURE (With Ore Transportation Cost)			134.23

SOURCE: Contractor estimates.

TABLE 15

ACTUAL VERSUS LIST PRICES FOR BARIUM CARBONATE

<u>Year</u>	<u>Shipment Quantity</u> (Thousand Tons)	<u>Value</u> ( <u>\$ Millions</u> )	<u>Unit Value</u> ( <u>\$/Ton</u> )	<u>List Price*</u> ( <u>\$/Ton</u> )
1963	54.5	5.9	108.25	111.50
1964	57.1	6.3	110.33	111.50
1965	59.9	6.6	110.18	111.50
1966	66.9	7.4	110.62	114.50
1967	59.6	6.6	110.73	114.50
1968	63.7	7.3	114.60	120.00
1969	59.7	6.7	112.22	120.00
1970	44.0	5.1	116.00	126.00
1971	47.2	5.8	122.70	132.00
1972	NA	NA	NA	150.00

\*List price for carload or truckload of regular 50-pound bags of barium carbonate, f.o.b. works, freight equalized.

NA--not available--data published for this year by USDC were incorrect.

SOURCES: Chemical Marketing Reporter, U.S. Department of Commerce and industry data.



Major end uses include textile grade fiberglass, borosilicate glass, porcelain enamels, and glazes. Some production, possibly 20 to 30%, is used captively in the manufacture of various borate chemicals.

Presently there are three producers of boric acid and anhydrous boric acid: U.S. Borax, the largest; Stauffer Chemical; and American Potash. U.S. Borax purchases most of its sulfuric acid from Stauffer and Stauffer purchases crude pentahydrate (Rasorite 46) from U.S. Borax. Statistics indicate that production was nearly 100% of capacity in 1970 but that it dropped to 76% in 1971 and increased again to 88% by 1972.

## 2. Market Characterization

### a. Market Size and Growth

Production of boric acid has been erratic in the past, ranging between 100,000 and 140,000 short tons, with a slightly increasing trend at the rate of about 1% over the last ten years. Table 16 shows data on production, imports, exports, and apparent consumption as reported by the U.S. Department of Commerce and the Tariff Commission. Production data, more exactly, represents "production for sale" rather than total output since at least one primary producer does not report quantities produced for captive use. Also, production data excludes U.S. Borax's output of "anhydrous boric acid" (95-96%  $B_2O_3$  product). Substitution of U.S. Borax's anhydrous boric acid for boric acid probably accounts for most of the decline in production of boric acid in the 1970's. However, industry sources indicate that currently the demand for boric acid is strong and that supply is inadequate. Markets are growing faster than supply.

Imports of boric acid have been negligible according to available data. Exports, like production, have vacillated but in general have grown at a more rapidly increasing rate than production. Data for boric acid exports were not separately broken out prior to 1965; however, since that time, the statistics show that exports have varied between 20,000 and 50,000 short tons per year, and in the last five years have averaged around 38,000 short tons. As a result of exports having increased at a rate faster than production, the rate of U.S. apparent consumption has shown a slightly decreasing trend and in 1972 was at a level of 93,700 short tons.

### b. Uses

There are two types of technical boric acid: granular boric acid of 56.2% boron trioxide content and anhydrous boric acid (boric oxide) of 99% boron trioxide content or 95.5% boron trioxide content. The latter is manufactured by U.S. Borax exclusively.

The major end uses for boric acid are textile glass fibers, heat-resistant glass, enamel frits and glazes, and herbicides. A growing market is that for fire retardant cotton batting. Table 17 shows the distribution of major uses for boric acid and oxide in 1963, 1969 and 1972.

TABLE 16

PRODUCTION, FOREIGN TRADE AND APPARENT CONSUMPTION  
OF BORIC ACID

(Thousands of Tons)

<u>Year</u>	<u>Reported Production*</u>	<u>Imports</u>	<u>Exports</u>	<u>Apparent Consumption</u>
1963	104.1	NA	NA	NA
1964	121.7	NA	NA	NA
1965	127.5	NA	21.2	106.3
1966	125.1	NA	28.3	96.8
1967	122.4	NA	23.8	98.6
1968	118.7	NA	37.9	80.8
1969	139.0	0.017	36.5	102.5
1970	137.5	0.011	52.4	85.1
1971	105.2	0.019	36.4	68.8
1972	121.4	NA	27.7	93.7

\*Excluding U.S. Borax's anhydrous boric acid. Because at least one primary producer does not report quantities produced and consumed at their plant, the production data is more representative of merchant production than of total output.

SOURCE: U.S. Department of Commerce.

TABLE 17

BORIC ACID\* END-USE PATTERN, 1963-1972

(Thousands of Tons)

	<u>1963</u>	<u>1969</u>	<u>1972</u>
Textile Glass Fibers	17.6	15.9	14.5
Heat-resistant Glass	17.8	12.3	11.2
Porcelain Enamel Frits & Glazes	4.6	8.9	8.1
Agriculture-Herbicides		1.8	1.6
Miscellaneous			
Chemical and Pharmaceutical Manufacture	14.7	} 63.6	58.3
Structural Products and Fire Retardants	7.5		
Other	33.2		
Exports	9.4	36.5	27.7
TOTAL	104.8	139.0	121.4

\*Excluding anhydrous boric acid produced by U.S. Borax starting in 1967.

SOURCE: Contractor estimates.



In textile glass fibers, boric acid is added for the purpose of adding durability to the glass. This type of fiberglass is used for thermal and electrical insulation, decorative and industrial fabrics, insect screening, and reinforced plastics. In finished glasses such as borosilicate glass (a heat-resistant glass with a low coefficient of expansion) boric acid is used to provide boric oxide for fluxing and also to limit the soda content of the finished glass. In porcelain, boric acid is used as a fluxing material, but also to control the coefficient of expansion of the enamel and thus to allow a better bond between the porcelain enamel coating and the metal substrate.

There are a variety of miscellaneous uses for boric acid. It is used by chemical manufacturers to make boron trifluoride, complex borohydrides, organic borates, boron trichloride and various inorganic borates. Anhydrous boric acid is also used in chemical manufacturing. In metallurgical applications, boric acid and several of its salts are used in the manufacture of welding and brazing fluxes. Boric acid is reacted with sodium hydroxide to make sodium metaborate which functions as a corrosion inhibitor in automotive antifreeze. Some boric acid is used in pharmaceutical preparations. It is also used as a fire retardant and stiffening agent for gypsum board. In the production of electrolytic capacitors, boric acid is used to etch the aluminum foil.

Several other miscellaneous uses are as follows: photographic developing compounds, preservative washes for citrus fruits, raw materials for certain dyes, sizing material in the production of basic nylon, conditioning agent for the manufacture of ammonium nitrate, raw material for the preparation of colors of various types of wallpapers, and emulsifying agents in the asphalt industry.

#### c. Substitute Products

There are few products which can be substituted for boric acid, with the exception of other borate forms (e.g., sodium borates) which may be used for price advantages if other required properties of boric acid are present. Anhydrous boric acid is a particularly strong competitor in glass and ceramic applications. Theoretically, boric acid can substitute for other borates if there is a price advantage and if sodium values or other properties can be introduced from another source. For example, in glass formulations, boric acid cannot be economically substituted for anhydrous borax unless its cost plus the cost of introducing sodium oxide ( $\text{Na}_2\text{O}$ ) is equal to or less than the cost of anhydrous borax.

#### d. Captive Requirements

We were unable to find any published information on the captive requirements of the boric acid producers. However, boric acid is used in the processing of boron derivatives and for manufacturing several chemical derivatives. Since many of these derivatives are borate chemicals produced by those who make boric acid, there is some captive use, possibly

20-30%. As noted in Table 16, the total production figure excludes captive production of at least one manufacturer and thus is low as an estimate of the total boric acid produced.

### 3. Supply Characterization

#### a. Manufacturing Routes

There are several manufacturing processes which can be applied to obtain boric acid and anhydrous boric acid (boric oxide). Required inputs are sodium tetraborate and sulfuric acid. Because sodium borates are produced in desert areas of California, boric acid is produced in California. The borax may be obtained from mines or lake brines; only one U.S. producer has a method for extracting borax from lake brines for the manufacturing of boric acid. The other producers extract their borax from mines to manufacture boric acid.

Most boric acid in the U.S. is manufactured from sodium borates by acidulating a saturated sodium tetraborate solution with hot sulfuric acid (98-99% concentration). U.S. Borax and Stauffer use this process. Very little, if any, boric acid is manufactured from calcium borates; this process is used primarily in Turkey and Europe.

American Potash (wholly-owned subsidiary of Kerr-McGee) is the only U.S. producer utilizing a process to manufacture boric acid from lake brines. Boric acid is obtained along with potassium and sodium sulfate by reacting the weak brines with a kerosine solution and then treating it with dilute sulfuric acid and activated carbon. By evaporation and crystallization the 99.9% pure boric acid product is separated from the sulfates.

Anhydrous boric acid (boric oxide, 95-96% boron trioxide) is manufactured by U.S. Borax primarily. By fusing borax with sulfuric acid in a furnace, anhydrous boric acid is obtained along with sodium sulfate. The two products are formed in layers and then separated while molten. Refined boric oxide is obtained by dehydrating orthoboric acid.

#### b. Producers

Table 18 shows the boric acid producers with their capacities and plant locations. Presently there are three producers of boric acid operating three plants with a total capacity of 139,000 tons, one of whom (U.S. Borax) also operates an anhydrous boric acid plant with 53,000 tons capacity. Of the boric acid capacity of American Potash, about 30% is based on acidulation of borax and the remaining 70% on the company's solvent extraction process.

Stauffer Chemical makes their boric acid from borax, specifically from Rasorite 46 (the crude pentahydrate) supplied by U.S. Borax.

The capacity of 62,000 short tons per year for U.S. Borax at Wilmington, California, represents their boric acid capacity; in addition, they have a capacity of 53,000 short tons for anhydrous boric acid at



TABLE 18

BORIC ACID PRODUCERS' CAPACITIES, 1972

<u>Company</u>	<u>Location</u>	<u>Average Capacity (Thousand Tons)</u>	<u>(% of Total)</u>
Kerr-McGee Corporation American Potash Chemical Corp., Subsidiary	Trona (Searles Lake), Calif.	43	22
Stauffer Chemical Co., Industrial Chemical Division	San Francisco, California	34	18
United States Borax & Chemical Corp., Owned by Borax (Holdings) Ltd. United Kingdom, which is owned by Rio Tinto-Zinc Corp. Ltd., United Kingdom	Wilmington, California	62	32
Total--Excluding U.S. Borax' anhydrous boric acid (Boron plant)		139	72
United States Borax & Chemical Corp.	Boron, California	53	28
Total Boric acid and boric oxide (anhydrous boric acid)		192	100.0

SOURCE: Industry sources.

Boron. In 1970, there were rumors of expansion of this capacity; however, fulfillment of this plan has not yet been reported. At both their Boron and Wilmington plants, U.S. Borax obtains most of its sulfuric acid from Stauffer Chemical. In total (boric acid plus anhydrous boric acid), U.S. Borax represents around 60% of total boric acid capacity.

#### c. Manufacturing Economics

Estimated costs of manufacturing boric acid are shown in Table 19.

#### 4. Supply/Demand Balance

The data indicate that the boric acid industry, excluding anhydrous boric acid, is operating pretty close to full capacity. Comparing Tables 16 and 18, we see that production was close to 90% of capacity in 1972.

#### 5. Prices

Table 20 shows actual versus list prices for boric acid. With the exception of the period 1965-1968, actual prices have been lower than list prices in bags. In 1963, 1971 and 1972, actual prices were significantly lower than the list price for granular in bulk. A comparison of list prices for bulk anhydrous (95-96%  $B_2O_3$ ) with bulk granular shows that the former has been 42-45% greater than the latter since 1969. Anhydrous of 99%  $B_2O_3$  has been more than double the price of either of the other two products.

### D. CALCIUM CARBONATE

#### 1. Summary

Calcium carbonate can be produced in three major forms: natural chalk whiting, prepared calcium carbonate (ground limestone or marble), and precipitated calcium carbonate (PCC). There are no chalk deposits in the U.S. appropriate for production of natural chalk whiting. Prior to World War II, the U.S. imported chalk whiting from Europe. However, during the war, when imports were cut off, substitutes were developed and post-war imports of whiting declined significantly. The U.S. presently uses ground limestone or marble and precipitated calcium carbonate. While more expensive, PCC is used in preference to the other calcium carbonate products when its properties of fineness, uniformity and purity are important or when it is more readily available. This report is directed towards PCC.

Reported U.S. production of PCC increased over the period 1963 to 1967 and then decreased until 1971; in 1972 it increased nearly 22% over the previous year, to a level of 220,900 tons. Including unreported production by paper companies, there may have been as much as 225,000 tons produced in 1972.

TABLE 19

ESTIMATED COST OF MANUFACTURING BORIC ACID

Physical Investment	
Process	\$4,000,000
Auxiliaries	<u>1,200,000</u>
Total	\$5,200,000
Capacity	182,000 lb/SD, 30,000 tons/yr
Operating Factor	3 shifts/day, 330 SD/yr

	<u>Quantity/Ton</u>	<u>\$/Unit</u>	<u>\$/Ton</u>
<u>Variable Costs</u>			
Raw Materials			
Borax ( $\text{Na}_2\text{B}_4\text{O}_7 \cdot 5\text{H}_2\text{O}$ )	2620 lbs	0.0202	53.00
Sulfuric Acid (100%)	880 lbs	0.008	7.04
Utilities			
Power	158 Kwh	0.0137	2.16
Cooling Water	22 M gal	0.05	1.10
Power Water	5.2 M gal	0.40	2.08
Natural Gas	4.2 MMBtu	0.597	2.50
Steam	15.00 M lbs	1.00	<u>15.00</u>
			82.88
Total Variable Costs			
<u>Semi-Variable Costs</u>			
Operating Labor	4 men/shift	\$4.31/m-h	5.04
Supervision	1 man	\$15,000/yr	0.50
Maintenance	5% of Investment/yr		8.66
Labor Overhead	60% of Labor & Supervision		<u>3.32</u>
			17.52
Total Semi-Variable Costs			
<u>Fixed Costs</u>			
Plant Overhead	40% of Labor & Supervision		2.22
Depreciation	6.2% of Depreciable Investment/yr		4.33
Taxes & Insurance	1.5% of Investment/yr		<u>2.60</u>
			9.15
Total Fixed Costs			
Subtotal			109.55
By-product Credit			
Sodium sulfate	1260 lbs	0.012	<u>15.12</u>
			94.43
TOATL COST OF MANUFACTURE			

SOURCE: Contractor estimates.

TABLE 20

ACTUAL VERSUS LIST PRICES, BORIC ACID  
(Dollars Per Ton)

Year	Actual Price, Boric Acid (excluding anhydrous)			List Price,* Boric Acid, Technical				
	Shipment Quantity (Thousand Tons)	Value (\$ MM)	Unit Value	Granular		Anhydrous		
				Bulk	Bags	99% B <sub>2</sub> O <sub>3</sub> Bags	95-96% Bulk	B <sub>2</sub> O <sub>3</sub> Bags
1963	91.5	10.3	112.7	106.00	112.00	335.80	--	--
1964	107.3	12.2	113.2	106.00	112.00	335.80	--	--
1965	111.6	12.6	112.8	106.00	112.00	335.00	--	--
1966	116.0	12.4	106.6	96.00	102.00	325.00	--	--
1967	101.6	10.0	98.7	96.00	102.00	325.00	--	--
1968	107.1	10.0	92.9	96.00	102.00	325.00	--	--
1969	110.9	12.1	108.8	106.00	116.00	375.00	151.00	161.00
1970	112.7	12.9	114.2	115.00	125.00		167.00	177.00
1971	96.3	10.8	112.8	126.00	138.00		185.00	197.00
1972	106.4	11.1	104.2	126.00	138.00		185.00	197.00
1973	NA	NA	NA	126.00	138.00		185.00	197.00

\*List prices were taken on or near July 1. Whenever a range of prices was given, the lowest was used.

SOURCES: U.S. Current Industrial Reports, and Chemical Marketing Reporter.



The U.S. Tariff Commission does not report PCC imports separately, but they are believed to be very small. In 1972, for the first time, exports for PCC (excluding pigment grade) were reported at a level of 8,900 tons or 4% of production. Production and consumption are thus nearly the same.

Presently there are four merchant producers (four plants) of PCC: BASF Wyandotte, Diamond Shamrock, Mississippi Lime and Pfizer. Because the paper industry is one of the major consumers of PCC, companies such as Champion Paper and Ecusta Paper produce PCC for captive use (three plants). In addition to being used as a paper coater and filler, PCC is also used in paint, rubber and plastics as a filler and/or extender. Another significant use is in the food and drug industry where PCC is used as a nutrient and pH controller.

## 2. Market Characterization

### a. Market Size and Growth

Table 21 presents Commerce Department data on production, foreign trade, and apparent consumption of precipitated calcium carbonate. Production increased at a rate of about 8% between 1963 and 1967, but then decreased at about 4% a year until 1971. In 1972, however, the declining trend was reversed and the highest level of production to date--more than 220,000 tons--was reached. Data for imports of PCC cannot be precisely determined because they are included with other calcium compounds in U.S. Tariff Commission import data. We believe, however, that the amount of imports is negligible. Export data are only available for 1972 when 8,900 tons of PCC (exclusive of pigment grades) were exported. This represents only 4% of production; it is unlikely that exports in previous years exceeded this 4% share of production. Apparent consumption of PCC for 1972 is 211,900 tons. However, this figure is believed to understate actual consumption by as much as 20% due to both captive production by paper companies not included in Commerce Department totals and some underreporting by merchant producers. Assuming negligible imports and a low level of exports, apparent consumption has closely paralleled production.

### b. Uses

PCC is used as a filler in a variety of products. The major consumer of PCC is the paper industry; it is estimated that as much as 75% of PCC production is used as a paper filler and coating pigment. Other uses include paint, rubber, plastics, food and drugs, inks, ceramics, insecticides, insulating compounds and welding rods, cosmetics, dentifrices, pharmaceuticals and anti-caking agents. PCC is also used in the production of chemical derivatives such as calcium lactate and calcium silicate.

In the paper industry, PCC is used as a filler for cigarette paper (to provide a steady combustion rate). As a paper coating material, PCC adds brightness, better opacity, and ink receptivity. The trend toward increased use of matte finished paper, for which chalk writing and Kaolin can be used, had a negative impact on the use of PCC.

TABLE 21

PRODUCTION, FOREIGN TRADE, AND APPARENT CONSUMPTION  
OF PRECIPITATED CALCIUM CARBONATE

(Thousands of Tons)

<u>Year</u>	<u>Production*</u>	<u>Imports</u>	<u>Exports**</u>	<u>Apparent Consumption</u>
1963	158.8	NA	NA	NA
1964	173.3	NA	NA	NA
1965	188.7	NA	NA	NA
1966	198.4	NA	NA	NA
1967	216.4	NA	NA	NA
1968	198.6	NA	NA	NA
1969	206.1	NA	NA	NA
1970	194.0	NA	NA	NA
1971	181.8	NA	NA	NA
1972	220.9	NA	8.9	212.0

\*Precipitated calcium carbonate.

\*\*Precipitated calcium carbonate, except pigment grade.

SOURCE: U.S. Department of Commerce, U.S. Tariff Commission.

PCC is used as a filler in better quality gloss paints. For the majority of paint applications, however, ground limestone is used because it is less expensive.

In the rubber industry, PCC (fine grades) is used to provide a semi-reinforcing effect and to improve extrusion and electrical insulation properties.

PCC as a filler improves impact strength and surface characteristics in polyester resins and provides mar resistance to polyvinyl chloride resins. However, PCC competes with other forms of calcium carbonate in the plastics market.

#### c. Substitute Products

There are several substitute products for PCC as has been mentioned above. PCC is more expensive than natural forms of calcium carbonate, but it has some property advantage which can be overcome by closely controlling processing conditions. Its purity and uniform particle size are advantageous. However, the high quality properties of PCC are not always required and frequently, for reasons of price or availability, other calcium carbonates or mineral fillers are substituted.

#### d. Captive Requirements

There is little published information available on captive requirements. However, there are certain paper companies who produce PCC for internal use. Some indication of captive consumption can be inferred from data published in the Current Industrial Reports. Table 22 presents captive consumption (excluding interplant transfers) derived from the difference between total production and total shipments including interplant transfers. As derived in this manner, captive consumption has historically been 10-15% of total production; in 1972 it was 11%. This estimate may be low, however, if there is a significant amount of interplant transfers.

### 3. Supply Characterization

#### a. Manufacturing Routes

There are several processes by which PCC can be produced. The simplest process involves calcining limestone to produce lime and carbon dioxide. The lime is slaked and reacted in slurry form with the carbon dioxide to produce PCC. A second process is that by which PCC is produced from waste streams from the Solvay process for production of soda ash. Finally, an alternate process uses waste product from water softening plants. However, this process produces a coarse and alkaline product.

#### b. Producers

It is difficult to obtain with certainty a list of all U.S. producers of calcium carbonate. The major producers are listed, along with their locations on Table 23.



TABLE 22

CAPTIVE CONSUMPTION OF CALCIUM CARBONATE

(Thousands of Tons)

<u>Year</u>	<u>Production</u>	<u>Total Shipments*</u>	<u>Implied Captive Consumption</u>
1963	158.8	139.7	19.1
1964	173.3	151.9	21.5
1965	188.7	162.8	25.9
1966	198.4	169.8	28.6
1967	216.4	193.8	22.6
1968	198.6	177.4	21.2
1969	206.1	180.9	25.2
1970	194.0	174.8	19.2
1971	181.8	162.5	19.3
1972	220.9	195.7	25.2

\*Including interplant transfers.

SOURCE: Current Industrial Reports.



TABLE 23

PRECIPITATED CALCIUM CARBONATE PRODUCERS

<u>Company</u>	<u>Location</u>	<u>Capacity (Thousand Tons)</u>	
		<u>(1971)</u>	<u>(1974-75)</u>
BASF, Wyandotte Corp. Industrial Chemical Group	Wyandotte, Michigan	60	65
Diamond Shamrock Chem. Co. Soda Products Div.	Painesville, Ohio	75	50
Mississippi Lime Co.	Ste. Genevieve, Missouri	45	36
Pfizer Inc. CK Williams & Co. Div.	N. Adams, Massachusetts	40	40
PPG Industries Inc.	Barberton, Ohio	20	--
<u>Captive Producers</u>			
Champion Paper Corp.	Hamilton, Ohio	25	20
	Pasadena, Texas		15
Ecusta Paper	Pisgah Forest, N. Carolina	40	40
TOTAL CAPACITY		305	266

SOURCE: Contractor estimates.

Mississippi Lime, Pfizer and BASF Wyandotte sell primarily to the paper industry and Diamond Shamrock and PPG Industries market to the rubber, plastics, and paint industries.

#### c. Manufacturing Economics

Estimated costs of manufacturing calcium carbonate are shown in Table 24.

#### 4. Supply/Demand Balance

Operating rates in recent years have averaged about 60-70% of capacity. Comparing Tables 22 and 23, it is apparent that production in 1971 was 181,800 tons whereas capacity was 305,000 tons. Production increased by 22% in 1972 to 220,900 tons.

#### 5. Prices

Table 25 shows actual versus list prices for PCC. The discrepancy between the actual and the list price during the last ten years suggests that the actual price is probably some weighted average of the list prices for different grades of PCC.

### E. CALCIUM HYDROXIDE

#### 1. Summary

Calcium hydroxide (also known as caustic lime, hydrated lime or slaked lime) is one of the three types of lime produced in the U.S. According to U.S. Bureau of Mines statistics, hydrated lime accounted for 12.8% of the total lime sold or used by producers in 1972. The largest volume product of the lime industry is quicklime which in 1972 accounted for 81% of the total production. The third type of lime produced is dead-burned dolomite (6.2% of total production).

In 1972, U.S. apparent consumption of calcium hydroxide was 2,642,000 tons, according to the Bureau of Mines. Of this total, less than 2% was imported; the remainder reflects the amount of hydrated lime sold or used by producers. An unknown but very small amount of hydrated lime is exported. National Lime Association figures for 1972 are 8% lower than the Bureau of Mines. (Data differences are discussed later in the section.) The main uses of this product are in construction and chemical or industrial manufacturing; a small percentage of sales go to agriculture. Competitive products include caustic soda and sodium carbonate for chemical neutralization, cement for mortar, asphalt for soil stabilization, and alum, ferric chloride, and polyelectrolytes for water treatment (phosphate removal).

Presently, there are 65 commercial plants producing hydrated lime. Capacity is not known, but operating rates are thought to be fairly

TABLE 24

ESTIMATED COST OF MANUFACTURING CALCIUM CARBONATE (PRECIPITATED)

Physical Investment:	\$ 6.5 Million
Capacity:	40,000 Tons/Year
Operating Factor:	3 Shifts/Day, 330 SD/Yr

	<u>Quantity/Ton</u>	<u>\$/Unit</u>	<u>\$/Ton</u>
<u>Variable Costs</u>			
Raw Materials			
Slaked Lime	0.75 tons	17.00	12.58
Utilities			
Fuel (Natural Gas)	1.73 MSCF	0.30	0.52
Power	388 Kwh	0.0137	<u>5.32</u>
TOTAL			\$18.42
<u>Semi-Variable Costs</u>			
Operating Labor	2 Men/Shift	\$4.31/m-h	1.65
Supervision	1 Supervisor	\$15,000/Yr	0.38
Maintenance	6% of Investment/Yr		9.75
Labor Overhead	60% of Labor and Supervision		<u>1.22</u>
TOTAL			\$13.00
<u>Fixed Costs</u>			
Plant Overhead	40% of Labor and Supervision		0.81
Depreciation	11.1% of Investment/Yr		18.04
Taxes and Insurance	1.5% of Investment/Yr		<u>2.44</u>
TOTAL			<u>\$21.29</u>
TOTAL COST OF MANUFACTURE			\$52.71

SOURCE: Contractor estimates.

TABLE 25

## ACTUAL VERSUS LIST PRICES FOR PRECIPITATED CALCIUM CARBONATE

Year	Total Shipments			List Price (\$/Ton)			
	(Including interplant transfers)	Value (\$MM)	Unit Value (\$/Ton)	Medium	Dense	Surface Treated	Ultrafine USP
	Quantity (Thousand Tons)						
1963	139.7	7.7	55.5	38.00	30.00		117.50
1964	151.9	8.4	55.1	38.00	30.00		117.50
1965	162.8	8.6	52.5	38.00	30.00		117.50
1966	169.8	9.1	53.7	38.00	30.00		117.50
1967	193.8	10.5	53.9	38.00	30.00	42.00	117.50
1968	177.4	10.0	56.1	38.00	30.00	42.00	117.50
1969	180.9	10.0	55.4	38.00	30.00	42.00	117.50
1970	174.8	9.9	56.4	55.00	35.00	60.00	125.00
1971	162.5	9.6	59.3	60.00	42.00	65.00	130.00
1972	195.7	12.1	61.6	60.00	42.00	65.00	130.00
1973	NA	NA	NA	65.00	44.00	72.00	130.00

\*List price data 1967-1973 represent the low list price for the first week in July; 1963-1966 represent the low price for the year.

SOURCES: U.S. Department of Commerce and Chemical Marketing Reporter.



close to 100%. Manufacturing cost components vary tremendously but are thought to total around \$17.00 per short ton or nearly 90% of the bulk price for the east. Fuel is an important input, thus the industry is suffering from rapidly rising costs.

## 2. Market Characterization

### a. Market Size and Growth

Differences in reported U.S. data on hydrated lime complicate a quantitative discussion on production. Table 26 presents U.S. production data published by the Bureau of Mines as well as by the National Lime Association. Bureau of Mines data represent hydrated lime sold or used by U.S. producers (except Puerto Rico), excluding regenerated lime, for the period 1963 to 1972. National Lime Association data, only available since 1969, was developed to reflect commercial production of hydrated lime, excluding lime slurry and milk of lime. Their data are lower than the Bureau of Mines by as much as 33% (1971) or as little as 8% (1972). Due to the availability of historical data from the Bureau of Mines for both production and end uses, the discussions below use these data. The reader should bear in mind, however, that these data apparently include lime slurry and milk of lime which, according to the Lime Association, should not be considered part of commercial hydrated lime production.

As can be seen in Table 26, the Bureau of Mines data indicate a steady but slow growth in production of hydrated lime sold or used by producers over the last ten years with the exception of 1968 and 1972. The apparent decrease in production in 1972 actually reflects a reclassification of milk of lime as quicklime rather than hydrate. With the closing of several plants in New England, imports increased dramatically starting in 1969, but still represent only a small share of total consumption (less than 2%). There are no explicit data on exports or hydrated lime; industry experts believe there is a small amount exported to Canada and the Caribbean.

### b. Uses

The main end users for hydrated lime are indicated in Table 27. The pattern over the period 1963 to 1972 shows that over half the production sold has been used for construction. Around 40% has been used for chemical and industrial needs and only 3% has been used for agricultural purposes. Hydrated lime is important in road construction for soil stabilization and, in general construction, as an ingredient for mortar, plasters, and masonry cements. In the chemical industry, it can be used for neutralization and bleaching for example, and also as an ingredient for pesticides. It also can be used in water softening.

### c. Substitute Products

For some end uses there are substitute products for hydrated lime. In some cases, this substitute may be quicklime. Depending on the quantity

TABLE 26

PRODUCTION, FOREIGN TRADE, AND APPARENT  
CONSUMPTION OF CALCIUM HYDROXIDE

(Thousands of Tons)

<u>Year</u>	<u>Production</u> *	<u>Imports</u>	<u>Exports</u>	<u>Apparent Consumption</u> *
1963	2,444	NA	NA	2,444
1964	2,551	.8	NA	2,552
1965	2,609	.5	NA	2,610
1966	2,669	.2	NA	2,669
1967	2,656	.5	NA	2,657
1968	2,364	.9	NA	2,365
1969	2,864 (2,449)	39.3	NA	2,903 (2,488)
1970	3,126 (2,278)	34.2	NA	3,160 (2,312)
1971	3,446 (2,310)	39.8	NA	3,486 (2,350)
1972	2,603 (2,404)	37.5	NA	2,642 (2,441)

\* Historical series of production represents Bureau of Mines data on hydrated lime sold or used by U.S. producers (except Puerto Rico) excluding regenerated lime. Data in parenthesis represent commercial production of hydrated lime (excluding lime slurry, milk of lime, and regenerated lime) as published by the National Lime Association (NLA). Apparent consumption is derived for the two series by adding imports to production; exports are assumed to be negligible. The Bureau of Mines data is significantly higher than that of the NLA over the period 1969-1971 because the former source includes some slurry reported as quicklime.

SOURCES: Bureau of Mines, National Lime Association, and U.S. Tariff Commission.

TABLE 27

END-USE PATTERN OF CALCIUM HYDROXIDE

	1963					
	Thousand Tons	%	Thousand Tons	%	Thousand Tons	%
Chemical and Industrial	865	39	910	40	1,138	44
Construction						
Soil Stabilization					840	32
General Construction					549	21
Total	1,255	57	1,282	57	1,388	53
Agricultural	85	4	65	3	84	3
Total Hydrated Lime Sold by Producers	2,205	100	2,257	100	2,611	100

SOURCE: U.S. Bureau of Mines, Mineral Industry Surveys.



of hydrated lime required, a company may decide to purchase quicklime and slake it into hydrated lime themselves. Usually, a company requiring over two carloads of hydrate per month will invest in their own slaking equipment unless they are short on storage space and prefer frequent deliveries of small quantities. For example, a small city may purchase hydrated lime for water softening whereas a large one may purchase quicklime and slake it themselves. Frequently, in metallurgy, water treatment, leather tanning, and some parts of the chemical industry quicklime and hydrated lime are interchangeable.

For chemical neutralization, caustic soda, sodium carbonate or limestone may be substituted. Caustic soda, for example, costs more but when used with sulfuric acid a soluble product is obtained whereas the neutralization product using lime slurry is not soluble.

In mortar, masonry cement is a competitor. In soil stabilization, some conditions clearly require hydrated lime and others clearly require Portland cement; however, for certain cases substitution between the two may occur. Since the price of cement and hydrated lime is about equal, other variables, such as availability, bear on the purchaser's decision. In a few cases of soil stabilization, asphalt may be substituted for hydrated lime. Finally, for sewage treatment including the removal of phosphates, substitutes such as alum, ferric chloride, and polyelectrolytes may be used.

#### d. Captive Requirements

There is some minor captive usage of hydrated lime in masonry cement and lime/fly ash base stabilization. Such uses are not reported and are an insignificant part of the total.

### 3. Supply Characterization

#### a. Manufacturing Routes

Hydrated lime is manufactured from quicklime which is manufactured from limestone. The first step of the process is the thermal decomposition of limestone to quicklime in a kiln. Limestone is crushed and added to the kiln, and then calcined for decomposition. The resultant quicklime is then removed from the kilns, and slaked to obtain hydrated lime. Requirements for obtaining the quicklime used in production of hydrated lime are 3,750 pounds of pure limestone and 5-8 million (av. 7 million) Btu of fuel per ton of quicklime. Of the total lime sold or used by producers in the U.S., around 12 to 15% is hydrated lime, 80% quicklime, and the rest dead-burned dolomite.

#### b. Producers

Presently, there are approximately 45 producers of calcium hydroxide with 65 plants. Their plant locations are shown in Table 28. Capacity information is not available and there is little captive usage of slaked lime.



TABLE 28

CALCIUM HYDROXIDE PRODUCERS

<u>State and Company</u>	<u>Location</u>
Alabama:	
Allied Products Company	Calera
Cheney Lime & Cement Company	Landmark
S.I. Lime Co.	Saginaw
Martin-Marietta Cement	Roberta
Arizona:	
Paul Lime Plant, Inc.	Douglas
The Flintkote Co., U.S. Lime Div.	Nelson
Arkansas:	
Rangaire Corporation	Batesville
California:	
Diamond Springs Lime Company	Diamond Springs
The Flintkote Co., U.S. Lime Div.	Richmond
	City of Industry
Pfizer, Inc.	Cushenbury
Stauffer Chemical Company	West End
Connecticut:	
Pfizer, Inc.	Litchfield
Florida:	
Chemical Lime, Inc.	Brooksville
Hawaii:	
Gaspro, Ltd.	Waianae
Hawaiian Commercial & Sugar Co., Ltd.	Paia
Illinois:	
Marblehead Lime Company	South Chicago
	Thornton
	Quincy
Iowa:	
Linwood Stone Products Co., Inc.	Linwood
Louisiana:	
S. I. Lime Co.	Morgan City
U.S. Gypsum Company	New Orleans

TABLE 28 (Continued)

CALCIUM HYDROXIDE PRODUCERS

<u>State and Company</u>	<u>Location</u>
Maryland:	
S.W. Barrick & Sons, Inc.	Woodsboro
Massachusetts:	
Lee Lime Corporation	Lee
Pfizer, Inc.	Adams
Missouri:	
Ash Grove Cement Company	Galloway
Mississippi Lime Company	Ste. Genevieve
Nevada:	
The Flintkote Company	Henderson
Ohio:	
National Gypsum Company	Gibsonburg
National Lime & Stone Company	Carey
Ohio Lime Company	Woodville
Pfizer, Inc.	Gibsonburg
U.S. Gypsum Company	Genoa
Oklahoma:	
St. Clair Lime Company	Sallisaw
Oregon:	
Ash Grove Cement Company	Ash Grove
Pennsylvania:	
Bethlehem Mines Corporation	Annville
G & W.H. Corson, Inc.	Plymouth Meeting
Marblehead Lime Company	Pleasant Gap
Mercer Lime & Stone Company	Mercer
National Gypsum Company	Bellefonte
Warner Company	Bellefonte
	Cedar Hollow
Puerto Rico:	
Puerto Rican Cement Company, Inc.	Ponce
South Dakota:	
Pete Lien & Sons	Rapid City
Tennessee:	
Tennessee Lime	Asbury
Williams Lime Manufacturing Company	Knoxville

TABLE 28 (Continued)

CALCIUM HYDROXIDE PRODUCERS

<u>State and Company</u>	<u>Location</u>
Texas:	
Austin White Lime Company	McNeil
Chemical Lime Company	Clifton
McDonough Bros., Inc.	San Antonio
Round Rock Lime Company	Blum
Texas Lime Company	Cleburne
U.S. Gypsum Company	New Braunfels
Utah:	
The Flintkote Company	Dolomite
Lakeside Lime, Inc.	Provo
Virginia:	
Chemstone Corporation	Dominion
M.J. Grove Lime Company	Stephens City
National Gypsum Company	Kimballton
The Virginia Lime Company	Kimballton
Washington:	
Domtar Chemicals, Inc.	Tacoma
West Virginia:	
Germany Valley Limestone Company	Riverton
Wisconsin:	
Cutler-Laliberte-McDougall Corporation	Superior
Rockwell Lime Company	Manitowoc
Western Lime & Cement Company	Green Bay
	Knowles
	Eden

SOURCE: Industry and association sources.

### c. Manufacturing Economics

Costs for lime manufacture vary significantly, primarily because of regional differences. Frequently, however, plants with high costs in one area are able to offset these costs in other ways. For instance, if a plant has high fuel costs, it may offset these by high thermal efficiency. If labor costs are high, they may be offset by automation. Another important and variable cost is that of kiln feed or stone. Other costs for the manufacture of quicklime include depreciation, interest, power, maintenance supplies and parts, testing (quality control), insurance, taxes, and administration. Depreciation is probably the most important of these. Almost all plants are suffering currently from fuel costs because the industry is very fuel intensive. It is estimated that total costs average around \$17.00 per short ton of hydrated lime.

### 4. Supply/Demand Balance

The industry reports that most plants are operating close to capacity.

### 5. Prices

Table 29 shows data on average selling price for all types of lime in comparison with list prices for the east for various grades of quicklime and chemical lime. The fact that the average price is lower than any of the list prices implies that actual prices most likely reflect a weighted average including lower prices.

## F. CARBON DIOXIDE

### 1. Summary

In 1972, U.S. consumption of carbon dioxide was about 1.48 million tons, almost all of which was derived from domestic production. U.S. consumption of carbon dioxide has increased at an annual compound growth rate of 9% for the period 1968-1972. In its use in refrigeration, carbon dioxide competes to some extent with liquid nitrogen, but in general, there are no substitute products. Almost 100% of carbon dioxide consumption is merchant supplied.

There are three major producers of carbon dioxide--Liquid Carbonic, a division of Houston Natural Gas; Cardox, a division of Chemetron; and Airco. There is an apparent overcapacity situation operating but problems with national distribution, regional demand, seasonal peaks, and sometimes spotty raw material availability necessitate this overcapacity.

### 2. Market Characterization

#### a. Market Size and Growth

The quantity of carbon dioxide produced in the United States has been growing steadily at an average rate of 5% per year since 1960. Production



TABLE 29  
ACTUAL VERSUS LIST PRICES FOR LIME  
(Dollars Per Ton)

<u>Year</u>	Average Selling Value <u>All Lime</u>	LIST PRICES (Carlot, 50,000 lbs.,work,East)				
		<u>Quicklime</u>		<u>Hydrated</u>		<u>Spray</u>
		<u>Bulk</u>	<u>Bags</u>	<u>Bulk</u>	<u>Bags</u>	<u>Bags</u>
1963	13.73					
1964	13.87					
1965	13.87					
1966	13.27					
1967	13.36	15.50			19.25*	19.25*
1968	13.39	15.50			19.25*	19.25*
1969	13.89	15.50			19.25*	19.25*
1970	14.49	15.50			19.25*	19.25*
1971	15.73	18.00	23.00	19.50	25.25	--
1972	16.72	18.00	23.00	19.50	25.00	--

\*For New York delivery, add \$6.29 freight charge

SOURCES: Chemical Marketing Reporter and U.S. Bureau of Mines.

for the period 1963 to 1972 are shown in Table 30. During the span 1968 to 1972, total production of carbon dioxide has increased at an average annual compound rate of about 9%. Production for 1974 will be approximately 1,385,000 tons and is expected to increase at a rate of about 8% per year to about 2,200,000 tons by 1980.

Carbon dioxide is shipped in three forms--solid (dry ice), liquid, and gas. Prior to 1962, more than 50% of shipments were in the form of dry ice, but dry ice shipments declined steadily while non-solid forms grew in the period 1968 to 1972 at an annual rate of about 15%. By 1972, dry ice represented about 25% of the total shipments. Shipments of solid carbon dioxide for the period 1974 to 1980 are expected to plateau at about 300,000 tons per year.

#### b. Uses

Table 31 gives the end-use breakdown for carbon dioxide in the United States. Refrigeration was the single largest end use for carbon dioxide in the period 1968-1972, and the use of bulk carbon dioxide is increasing. There has also been an increase in the use of carbon dioxide as a refrigerant for certain industrial uses--to speed up the cooling cycle in the blow molding of plastics, to chill rubber and plastic items before machining and grinding, and for low temperature environmental testing. The increased consumption of carbonated beverages, paced by the introduction of low calorie diet colas has increased carbon dioxide usage for carbonation at about 8% per year during the same period.

Carbon dioxide is the cheapest inerting gas suitable for use in welding mild steel and is gaining wide acceptance among auto manufacturers. Carbon dioxide is used in the chemical industry to manufacture salicylates, urea, soda ash, and a series of carbonates and bicarbonates. It is also used in the hardening of sand cover at foundries, oil well fracturing, atmospheric enrichment for greenhouses, fire extinguishers and an inerting gas in the production of food.

#### c. Substitute Products

Liquid nitrogen has been the only challenge to carbon dioxide in the refrigeration market. In food refrigeration, carbon dioxide is beginning to have more impact. It is more economical than nitrogen (although more expensive than mechanical units). Liquid carbon dioxide is showing promise as a freezing medium in such areas as meats and dessert foods.

#### d. Captive Requirements

Most market carbon dioxide is a mechanical conversion product of impure carbon dioxide which is a by-product of ammonia and hydrocracking plants. Neither these sources, nor the converters require any significant amounts of carbon dioxide in their own operations. A small volume is used captively by some refineries and breweries.

TABLE 30

CARBON DIOXIDE PRODUCTION

(Thousands of Tons)

<u>Year</u>	<u>Liquid and Gas</u>	<u>Solid</u>	<u>Total</u>
1963	543	434	977
1964	584	423	1,007
1965	665	421	1,086
1966	703	379	1,082
1967	717	372	1,089
1968	684	374	1,058
1969	802	364	1,166
1970	815	321	1,135
1971	1,027	317	1,344
1972	1,175	307	1,481

SOURCE: U.S. Department of Commerce.

TABLE 31

CARBON DIOXIDE END-USE BREAKDOWN

(Thousands of Tons)

<u>Industry</u>	<u>1968</u>	<u>1972</u>	<u>% Share</u>	<u>% Growth 1968-1972</u>
Refrigeration	380	440	30	4
Carbonation	220	300	20	8
Welding & Inerting	170	220	15	7
Chemicals	110	150	10	8
Other (Foundries, Oil Well Fracturing, Fire Extinguishers, etc.)	220	370	25	13
TOTAL	1,058	1,480		9

SOURCE: Contractor estimates.



### 3. Supply Characterization

#### a. Manufacturing Routes

Carbon dioxide is purified from gas mixtures that are produced in a wide variety of processes or are found under certain natural conditions. Currently, the largest source of carbon dioxide is as a by-product of anhydrous ammonia manufacture from natural gas; important, but smaller quantities come from (1) hydrocracking, (2) the burning of lime, and (3) certain natural gas wells. The production of carbon dioxide from the combustion of fuels, though at one time important, has become uneconomical, and most such plants have been shut down.

In the purification process, the impure carbon dioxide is compressed and cooled in a series of steps to condense out the water vapor. The purified gas is then cooled and compressed to liquid. In some plants it is necessary to remove organics from the stream. This is done with permanganate scrubbing.

#### b. Producers

Table 32 shows plant locations and capacities of the 11 carbon dioxide producers (55 plants). Three producers, Liquid Carbonic, Cardox and Airco, account for over 75% of total U.S. capacity. The term "capacity" is somewhat misleading when considering carbon dioxide since in some cases the producers purify a stream of carbon dioxide; in others, they purchase carbon dioxide which is purified by the raw material supplier.

#### c. Manufacturing Economics

Estimated manufacturing economics for carbon dioxide are shown in Table 33. The cost estimates are based on a plant with a 200 ton per day capacity with a fixed investment of \$2 million, and operating 300 days per year. Raw material represents about 25% of the total cost of manufacture of \$8.60 per ton.

New plants coming on stream tend to have larger capacities. In the future, plants of 500 ton-per-day capacity and fixed investment of \$3.5 million will be more typical.

### 4. Supply/Demand Balance

U.S. carbon dioxide capacity, shown in Table 32 would appear to be far in excess of production. However, a number of factors combine to necessitate this overcapacity. First, since the carbon dioxide is purified from a by-product stream, the producer either contracts for the entire stream, or none, therefore sometimes necessitating a plant larger than required; second, the parent plant is not always operating and thus the carbon dioxide stream is often only sporadically available; and third, demand is regional and seasonal, forcing the producer to make more capacity

TABLE 32

CARBON DIOXIDE PRODUCERS

<u>Company</u>	<u>Location</u>	<u>Capacity</u> (Tons/Day)
Liquid Carbonic Div. Houston Natural Gas	Augusta, Ga.	200
	Dodge City, Kansas	200
	Fontana, Cal.	20
	Fort Dodge, Ia	200
	Fort Madison, Ia.	250
	Hanford, Cal.	100
	Helena, Ark.	200
	Los Angeles, Cal.	250
	New Orleans, La.	300
	Palmerton, Pa.	50
	Philadelphia, Ia.	250
	Seattle, Wash.	75
	Tampa, Fla.	100
	Taft, Cal.	50
	Texas City, Texas	200
	Toledo, Ohio	180
		<u>2,625</u>
Airco	Brea, Cal.	150
	Clinton, Ia.	300
	East Dubuque, Ia.	150
	Hopewell, Va.	250
	Lathrop, Cal.	200
	Lawrence, Ka.	200
	Lima, Ohio	300
	Olean, N.Y.	120
	Yazoo City, Miss.	150
		<u>1,820</u>
Chemetron, Cardox Div.	Atchison, Kansas	100
	Brea, Cal.	125
	Delaware City, Del.	520
	East Dubuque, Ia.	100
	Fontana, Cal.	60
	Green Springs, Ohio	300
	Jeffersonville, Ind.	80
	Kerens, Texas	150
	Lathrop, Cal.	100
	Lawrence, Kansas	30
	Memphis, Tenn.	360
	Morris, Ill.	110
	Pryor, Okla.	50
		<u>2,335</u>

TABLE 32 (Continued)

CARBON DIOXIDE PRODUCERS

<u>Company</u>	<u>Location</u>	<u>Capacity</u> (Tons/Day)
Thermice	Philadelphia, Pa.	400
	Mercatine, Ia.	120
	Lima, O.	<u>100</u>
		620
Carbonic Ind.	Brandenberg, Kentucky	100
	Chattanooga, Tenn.	<u>135</u>
		235
South West Cryogenic	Deek Park, Texas	150
	Mormetta, W. Va.	200
	Luling, La.	<u>80</u>
		430
Diamond Shamrock	Dumas, Tex.	50
	Pryor, Okla.	50
	Solano, N. Mex.	<u>125</u>
		225
Carbonaire	Palmerton, Pa.	50
Industrial Air Products	Kenewick, Wash.	70
Union Ice	Brea, Cal.	125
	Lathrop, Cal.	<u>60</u>
		185
Dye Corp (Colorado Carbonic)	Benson, Ariz.	100
	Cortez, Colo.	<u>100</u>
		200
TOTAL		8,795

SOURCE: Contractor estimates.

TABLE 33

ESTIMATED COST OF MANUFACTURE OF CARBON DIOXIDE

Plant Capacity                      200 tons per day  
Fixed Investment                    \$2.0 million

	<u>Unit</u>	<u>\$/Unit</u>	<u>Unit/Ton</u>	<u>\$/Ton</u>
Raw Material				
95% CO <sub>2</sub>	ton	1.60	1.25	2.00
Chemicals				.40
Utilities				
Power				1.65
Labor				0.35
Overhead				0.25
Maintenance				0.60
Depreciation				3.00
Taxes and Other				0.35
TOTAL COST OF MANUFACTURE				8.60

SOURCE: Industry estimates.



available for peak periods. These factors, added to an approximate 20% efficiency loss, help put actual capacity more in line with production.

#### 5. Prices

Price declines have plagued the industry since the early 1960's. Table 34 lists the value of shipments in the period 1968 to 1972. Prices for liquid and gas have fallen from \$39 per ton in 1968 to \$22.00 per ton in 1972. Total dollar volume has remained about constant in spite of large tonnage increases during that period. It is likely that prices will begin to rise, primarily because all commodity prices are rising, and because carbon dioxide is to some degree energy dependent.

#### G. CARBON MONOXIDE

##### 1. Summary

Total U.S. carbon monoxide consumption in 1972 was about 610 million pounds which was all derived from domestic production. U.S. out-

TABLE 35

#### CONSUMPTION OF CARBON MONOXIDE

<u>Year</u>	<u>Millions of Pounds</u>
1967	340
1968	355
1970	430
1972	610
1973	720

consumption will be about 1,420 million pounds. This impressive growth rate will be due primarily to new capacity being installed for the production of acetic acid by direct carbonylation.

Since the product is considered hazardous and travels with difficulty in special tanktrucks (at special prices) there is essentially no import/export market.

#### b. Uses

The major application for carbon monoxide is in the direct carbonylation process for the production of acetic acid. This process is a Monsanto development which eliminates several intermediate rate steps in synthesis and is expected to make other synthesis routes obsolete. Carbon monoxide requirements for acetic acid are currently about 200 million pounds per year. Since acetic acid is in tight supply, carbon monoxide demand will grow from 200 million pounds in 1974 to 400 million pounds by 1980.

Table 36 shows carbon monoxide demand in oxo-alcohols and phosgene production (for isocyanate synthesis) growing at about 10% per year through 1980. Carbon monoxide demand for acrylates production will plateau since the acetylene route to acrylates is now obsolete. Current carbon monoxide capacity for use in acrylates will continue to operate but there will be no new capacity installed. Therefore carbon monoxide consumption in acrylates will remain constant at 60 million pounds per year through 1980. Other applications of carbon monoxide are in miscellaneous chemicals such as sodium formate for food preservation and new synthesis using direct carbonylation. Carbon monoxide demand for major end uses, as shown in the table, is expected to be about 800 million pounds in 1974 and will grow at an average annual compound rate of about 10% through 1980, putting demand for these applications at about 1,430 million pounds in 1980.

#### c. Substitute Products

Although acetylene based acrylate plants are phasing out, there are no significant alternate manufacturing routes for the other major carbon monoxide consuming products. Direct carbonylation is a new technology which industry sources expect to encroach on synthesis routes to other chemicals, thus broadening the carbon monoxide market.

#### d. Captive Requirements

There are about 13 carbon monoxide facilities in the United States. Of these, Air Products and Liquid Carbonic are the major merchant carbon monoxide producers with smaller market quantities available from Borden's Geismar, Louisiana, facility. All others are captive. In 1974, merchant shipments will be about 300 million pounds or about one-third of the total market.

TABLE 36

U.S. CONSUMPTION OF CARBON MONOXIDE  
BY END USE

(Millions of Pounds)

	<u>1968</u>	<u>1970</u>	<u>1972</u>	<u>1974</u>	<u>1980</u>
Oxo alcohols	180	220	270	325	580
Phosgene	90	120	145	175	310
Acrylates	60	60	60	60	60
Acetic Acid	---	---	100	200	400
Other	<u>25</u>	<u>30</u>	<u>35</u>	<u>40</u>	<u>80</u>
TOTAL	355	430	610	800	1,430

SOURCE: Contractor estimates.

### 3. Supply Characterization

#### a. Manufacturing Routes

Carbon monoxide is manufactured by catalytically reacting methane, air and water vapor at elevated temperatures to form a mixture of hydrogen, carbon monoxide, and carbon dioxide. The carbon dioxide is scrubbed from the gas stream by the use of amines and the hydrogen and carbon monoxide are then separated, purified and compressed.

#### b. Producers

There are now 13 carbon monoxide manufacturing facilities in the United States. Producers, locations and capacities are shown in Table 37. All the producers shown, except for Air Products and Liquid Carbonics (and to a lesser extent, Borden) supply captive requirements only. No producer is integrated back to natural gas required for carbon monoxide manufacture.

#### c. Manufacturing Economics

Estimated costs for manufacturing carbon monoxide from natural gas are shown in Table 38. Estimates are based on a plant with a daily capacity of 0.7 MM SCF and a fixed investment of \$3.4 million. This is equivalent to about 37 tons per day and is a representative size for capacity already in place. However, future plants will be much larger, in the 5 MM to 25 MM SCF/SD capacity range price. Current trends are to centralize production and to take advantage of the economies of scale.

Table 38 shows that raw materials represented a considerable portion (about 23%) of the cost of manufacture. Based on this raw material cost and attaching a minimum fuel credit for hydrogen, the cost of manufacturing is about \$4.00 per MSCF, or 5.4¢ per pound. Since carbon monoxide is sold primarily "over the fence" with long-term contracts, it is difficult to estimate profitability. Industry sources indicate that a range of 12 to 15% gross margin would be a reasonable estimate.

### 4. Supply/Demand Balance

Carbon monoxide production is currently running at about 80 to 90% of capacity. Demand exceeds supply and production has been hampered to some extent by material shortages. Direct carbonylation techniques and increasing demand for carbon monoxide in acetic acid manufacturing will result in a 55 to 60% increase in capacity over the next six years.

### 5. Prices

As noted elsewhere, carbon monoxide is sold over the fence, with long-term contracts and therefore no published prices are available. Reasonable estimates put the pipeline price at about \$4.60 MSCF (natural gas at \$0.925 per MSCF) for a 1 MMCF day plant, and the liquid over the road price at about \$6 to \$7 per MSCF. Pipeline price for a 5 MMCF day plant



TABLE 37

CARBON MONOXIDE PRODUCERS

<u>Company</u>	<u>Location</u>	<u>Capacity</u> (MM CFD)
Air Products	La Porte, Texas	8.0
	Belle, W. Va.	0.5
Allied Chemical	Marcus Hook Pa.	3.0
Baychem (Mobay)	New Martinsville, W. Va.	3.0
Borden	Geismar, La.	3.0
Dow	Freeport, Texas	1.0
du Pont	Belle, W. Va.	2.0
Houston Natural Gas (Liquid Carbonic)	Geismar, La.	2.8
Monsanto	Texas City, Texas	8.0
Olin	Lake Charles, La.	1.7
Rohm & Haas	Deer Park, Texas	1.5
Sun Olin	Claymont, Del.	2.0
Union Carbide,	S. Charleston, W. Va.	<u>2.0</u>
		38.5

SOURCE: Contractor estimates.

TABLE 38

ESTIMATED COST OF MANUFACTURING CARBON MONOXIDE

Physical Investment:	Process	\$2,700,000
	Auxiliaries	<u>700,000</u>
	Total	\$3,400,000
Capacity:	700 MSCF/SD, 238 MMSCF/Yr	
Operating Factor:	3 shifts/day, 340 SD/Yr	

<u>Variable Costs</u>	<u>Quantity/MSCF</u>	<u>\$/Unit</u>	<u>\$/MSCF</u>
Raw Materials			
Natural Gas	1.85 MSCF	0.50	0.925
Catalysts			0.040
Utilities			
Power	21 kwh	0.0137	0.288
Cooling Water	2.34 M gal	0.05	0.117
Boiler Feed Water	17.5 gal	0.001	0.018
Misc. Chemical			<u>0.02</u>
Total			1.407
<u>Semi-Variable Costs</u>			
Operating Labor	2 men/shift	\$4.31/m-h	0.317
Supervision	1 shift foreman	\$15,000/yr	0.063
Maintenance	4% of Investment/yr		0.571
Labor Overhead	60% of Labor & Supervision		<u>0.228</u>
Total			1.179
<u>Fixed Costs</u>			
Plant Overhead	40% of Labor & Supervision		0.136
Depreciation	11.1% of Investment/yr		1.586
Taxes & Insurance	1.5% of Investment/yr		<u>0.214</u>
Total			<u>1.936</u>
TOTAL COST OF MANUFACTURE			4.522
By-Product Credit			
Hydrogen	3 MSCF	0.162	<u>(0.486)</u>
			4.036

SOURCE: Contractor estimates.

would be about \$3.00 per MSCF. Future pricing depends almost entirely on the cost of natural gas, which has already risen in Houston to \$1.30 per MSCF in early 1974 and will probably be about \$2.00 per MSCF before the end of the year. Therefore, future carbon monoxide prices can be expected to increase dramatically.

## H. CHROME PIGMENTS

### 1. Summary

Total U.S. production in 1972 for the five chrome pigments (chrome green, chrome oxide green, chrome yellow and orange, molybdate chrome orange and zinc yellow) plus iron blue was an estimated 66,000 tons, one-half of which was represented by chrome yellow and orange. Imports have been increasing and in 1972 represented approximately 16% of total U.S. output. Exports, primarily to Canada and Viet Nam, totaled less than 200 tons in 1972. Apparent U.S. consumption in 1971 totaled 70,800 tons. Although data for the early 1960's are not available, the U.S. market for chrome pigments and iron blue has been expanding slowly, with the most rapid relative growth being shown by molybdate chrome orange, chrome yellow (and orange) and chrome oxide green.

The major uses for these inorganic pigments are in paint, printing ink, floor products and paper. Specialty applications are in ceramics, cement, and asphalt roofing. Captive requirements by the U.S. producers are minimal.

There are four major U.S. producers (with production of three or more of the individual products) and seven minor producers. In general, the producers are neither integrated back to raw materials (e.g., sodium bichromate) nor forward to the end products.

Plant prices in 1972 varied between \$760 and \$1,300 per ton depending upon the specific product. The weighted average price in 1972 was an estimated \$900 per ton. In general, plant prices have been increasing, reflecting higher cost raw materials and fuels.

### 2. Market Characterization

#### a. Market Size and Growth

U.S. production data for chrome pigments for the period 1963 through 1972 are shown in Table 39. As indicated by these data, U.S. production has been increasing for chrome oxide green, chrome yellow and orange, and molybdate chrome orange. The most rapid growth (6.0% per year on a compound basis) has been demonstrated by molybdate chrome orange followed by chrome yellow and orange at 2.7% per annum compounded and chrome oxide green with average annual compound growth of 2.0% in the ten-year period. Production of iron blue has been essentially static at between 5,000 and 6,000 tons per year. Production of chrome green and zinc yellow has shown

TABLE 39

PRODUCTION OF CHROME PIGMENTS  
(Thousands of Tons)

<u>Year</u>	<u>Chrome Green</u>	<u>Chrome Oxide Green</u>	<u>Chrome Yellow</u>	<u>Molybdate Chrome Orange</u>	<u>Zinc Yellow</u>	<u>Iron Blues</u>	<u>Total</u>
1963	2.87	5.22	24.75	8.44	6.86	5.03	53.17
1964	3.11	5.61	26.52	9.34	7.77	5.04	57.39
1965	3.06	6.40	29.25	9.45	7.95	5.48	61.59
1966	2.96	6.85	31.41	10.86	8.27	5.57	65.92
1967	2.74	5.19	30.69	10.36	7.81	5.77	62.56
1968	2.83	6.23	32.79	11.38	7.41	6.05	66.69
1969	2.62	5.86	32.00	11.37	7.29	5.84	64.98
1970	2.55	6.75	32.45	11.02	5.75	5.21	63.73
1971	2.71	6.58	29.03	11.38	5.57	5.39	60.66
1972	NA	6.16	33.77	12.41	5.66	5.19	66.00*

SOURCE: U.S. Department of Commerce.

\*Estimated.



TABLE 41

EXPORTS OF CHROME PIGMENTS

<u>Year</u>	<u>Quantity</u> (Thousands of Tons)	<u>Value</u> (\$ Millions)
-------------	----------------------------------------	-------------------------------

Because of such differences, chrome greens are also often designated as "nitrate" greens or "acetate" greens.

Cp (pure color) chrome greens have great opacity and hiding power, high tinting strength, and good brilliance. Also, they are relatively inexpensive. The "acetate" greens are usually somewhat less permanent in mass-tone than are the "nitrate" greens, although all chrome greens tend to darken on exposure, in both masstone and tints. They are not resistant to alkalies nor to acids. They do not bleed but are subject to change of tint or color when used in paints and enamels containing oils that dry by oxidation, which tends to reduce the iron blue during prolonged storage. Upon application and drying of the paint, most of the original color is restored by reoxidation of the blue.

The cp chrome greens find wide application in many kinds of paints such as house paints, sash and trim paints, enamels, both air-drying and baking, flat paints, and also in printing inks, lacquer, calcimines, oil-cloth, paper, etc.

(2) Chrome Oxide Green. Chromium oxide green comprises two different pigments. The principal product is the anhydrous oxide,  $\text{Cr}_2\text{O}_3$ , but a certain amount of hydrated chromic oxide, or Guignet's green, is also manufactured. Chromium oxide green pigment is almost pure chromium oxide,  $\text{Cr}_2\text{O}_3$ , the commercial products analyzing 98.5% minimum of  $\text{Cr}_2\text{O}_3$ .

Chrome oxide green's resistance to alkalies, acids, and high temperatures, and its superlative fastness to light make it valuable for use as a colorant in Portland cement, ceramic-tile glazes, rubber, alkali-proof printing inks, limeproof paints, concrete and stucco paints, and bridge paints. It finds special use in coloring cement and in green granules for asphalt roofing. An interesting application is in camouflage paints, since the reflectance spectrum of chromic oxide resembles that of green foliage.

phosphate, to extra deep orange shades which are almost pure basic lead chromate,  $\text{PbO} \cdot \text{PbCrO}_4$ .

The chrome yellows cover the range of hues from light greenish yellow to reddish medium yellow and are among the most important groups of colored synthetic pigments.

In the group of chrome yellows, the light shades (primrose and lemon) constitute one subgroup while the medium yellow makes the other subgroup. The medium yellow shade, also known as middle chrome, is essentially pure normal lead chromate,  $\text{PbCrO}_4$ .

The chrome yellows are bright, clean colors with good hiding power and good resistance to fading in either mass color or tints. They are soft, grind easily, and are not reactive with most paint vehicles. Their durability for exterior use is generally good, although they do darken on exposure and are susceptible to blackening in the presence of hydrogen sulfide. They have poor resistance to alkali and discolor when subjected to high temperature, as in baking. Their many good qualities and relatively low cost make them very useful pigments in many kinds of paints and lacquers, traffic line paints, printing inks, papers, linoleum, leather finishes, etc. They are also used in calcimines and water paints which are not alkaline. Large quantities of chrome yellows are used with iron blues in the manufacture of the chrome green pigments.

The chrome orange group includes colors from slightly redder than the medium yellows to extra deep-red orange. All chrome oranges contain basic lead chromate,  $\text{PbO} \cdot \text{PbCrO}_4$ , which is present in increasing proportion to the normal lead chromate as the color becomes redder and deeper. The extra deep shade is the most basic and contains very little of the normal salt.

The properties of chrome oranges are generally similar to those of the chrome yellows, with the following exceptions. The basic character of the chrome oranges makes them more resistant to alkalies and less resistant to acids. Their large crystals make for improved lightfastness and lower hiding power and, at the same time, make them more sensitive to overgrinding, which causes the color to become lighter and yellower. The general uses are the same as given for medium chrome yellow and, in addition, the darker shades are used in rust-inhibitive primers and paints for use on ferrous metals. A specific bright red-orange shade of basic lead chromate, known as International Airways Orange, is a standard color for airport markings.

(4) Molybdate Chrome Orange. The molybdenum oranges, a unique group of very strong and brilliant pigments are essentially coprecipitated mixed crystals of lead chromate, lead sulfate, and lead molybdate,  $\text{PbMoO}_4$ .

The molybdenum oranges are characterized by their strong and brilliant color, very high hiding power, and high tinting strength. Despite costing more than the chrome oranges, they are economical to use because of their



high strength. They have poor resistance to alkali and, on exposure to light, darken more than do the basic chrome oranges. They are used in many kinds of paints, enamels, and lacquers, and are especially useful in mixtures with organic red toners to produce economical light-red colors of good brilliance. Use is made of them in floor coverings and printing inks.

(5) Zinc Yellow. Zinc yellow is a complex compound of zinc, potassium, and chromium having the approximate composition  $4\text{ZnO} \cdot \text{K}_2\text{O} \cdot 4\text{CrO}_3 \cdot 3\text{H}_2\text{O}$ .

Zinc yellow or "zinc chromate" has been known as a permanent pale greenish yellow pigment for many years, and was formerly used where lead chromates darkened due to exposure to hydrogen sulfide. It was found about 1935 that its limited water solubility, which was disadvantageous to its use as a pigment, made it valuable as an inhibitive pigment for prime-coating metal; and it has enjoyed a sizable and growing market. However, the use during World War II of nearly 12,000 tons per year, largely on ships and aircraft, has never been equaled.

Zinc yellow is sparingly soluble in water and chromate ions are present in its solutions. This feature, and also its properties as a mild base, account for its wide use as a pigment for corrosion-resistant primers, especially those for the nonferrous alloys of aluminum and magnesium. Zinc yellow is compatible with red lead and is used in conjunction with it in structural steel priming, as well as in combination with ferric oxide pigments. It forms an ingredient of dips for automotive bodies. It does not bleed in solvents and is better than chrome yellows in resistance to discoloration by sulfides. Compared to the chrome yellows, it is considerably lower in hiding power and tinting strength.

In addition to its most important use in primers, zinc yellow is used also in decorative finishes but almost always in combination with other color pigments such as hydrated chromium oxide. If used as the sole color pigment (e.g., in yellow exterior enamels) it weathers to an undesirable dull greenish shade. It is also used to make zinc green pigment, a precipitated mixture with iron blue.

(6) Iron Blues. The iron blues are very strong pigments which may appear almost black in the full color. They are produced in a range of masstones from a reddish, somewhat muddy or plumlike color to an intense jet-black masstone. When iron blues are reduced by mixing with a white opaque pigment, the shade of the tints will be found to range from a reddish blue to a greenish blue.

Iron blues are used in all kinds of paints and enamels, such as sash and trim paints, automotive enamels, lacquers, and "metallic" finishes. They are also used extensively in inks and printing inks, carbon-paper inks, crayons, linoleum, composition flooring, paper, laundry blues, etc. For use in making chrome greens the green shades of the iron blues are preferred.

End use applications for chrome colors and iron blues are summarized in Table 43.

### c. Captive Requirements

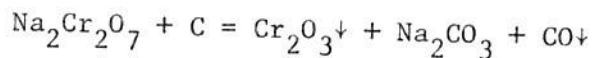
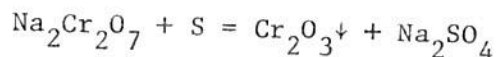
With the exception of chrome yellow and orange, Commerce Department data are withheld for commercial shipments of the chrome pigments and iron blue, from which captive consumption quantities could be inferred. However, based on the identity of the pigment producers and the end-use applications for chrome pigments it is apparent that captive requirements are relatively small. This conclusion is supported by the data for chrome yellow and orange as shown in Table 44. For the period 1963 through 1972 apparent captive consumption of chrome yellow and orange has averaged 8 to 12% of production. Chrome yellow is used captively for the production of other pigments (primarily chrome green), paint and ink.

## 3. Supply Characterization

### a. Manufacturing Routes

(1) Chrome Green. To make chrome green, chrome yellow and iron blue are physically mixed prior to grinding or coprecipitated from solution and then dried, ground, and packaged.

(2) Chrome Oxide Green. The currently favored method of preparing chromic oxide is by the calcining of sodium bichromate with sulfur or carbon in a reverberatory furnace.



Sodium sulfate from the first reaction above or soda ash from the second, is removed by washing, and the chromic oxide is filtered, dried and packaged. Chromic oxide for pigments is made with sulfur; that for aluminothermic chromium is made with charcoal or some other low-sulfur carbonaceous material.

Guignet's green (hydrated chromic oxide) results from the firing of a mixture of potassium dichromate and boric acid at about 550°C. The product is leached, filtered, washed, and dried. The pigment product is about 81% chromic oxide, 17% water, and about 2% boric acid (formerly considered necessary but now regarded as an impurity).

(3) Chrome Yellow and Orange. Chrome yellow pigment is basically a mixture of lead chromate, lead sulfate, and zinc sulfate, whereas chrome orange pigment contains basic lead chromate and lead sulfate. The primary ingredient of chrome yellow pigment is lead chromate, which is produced



TABLE 43

END-USE APPLICATIONS FOR CHROME COLORS

<u>End-Use</u>	<u>Chrome Green</u>	<u>Chrome Oxide Green</u>	<u>Chrome Yellow</u>	<u>Molybdate Chrome Orange</u>	<u>Zinc Yellow</u>	<u>Iron Blues</u>
Paint	✓	✓	✓	✓	✓	✓
Ink	✓	✓	✓	✓		✓
Floor Tile	✓		✓	✓		✓
Paper	✓		✓			✓
Ceramics		✓				
Cement		✓				
Asphalt Roofing		✓				
Other Pigments			✓		✓	✓
Miscellaneous	✓	✓	✓			✓

SOURCE: Contractor estimates.

TABLE 44

APPARENT CAPTIVE CONSUMPTION OF CHROME YELLOW  
AND ORANGE

<u>Year</u>	<u>Total Production</u>	<u>Total Shipments</u>	<u>Commercial Shipments</u>	<u>Apparent Captive Consumption</u>
	(-----	Thousands of Tons	-----)	(%)
1963	24.75	24.54	21.99	11.2
1964	26.52	26.38	23.20	12.5
1965	29.25	27.58	24.86	15.0
1966	31.41	31.08	28.04	10.7
1967	30.69	29.77	26.89	12.4
1968	32.79	32.02	29.11	11.2
1969	32.00	32.08	29.79	6.9
1970	32.45	31.71	29.43	9.3
1971	29.03	28.33	26.83	7.6
1972	33.77	31.99	29.49	12.7

SOURCE: U.S. Department of Commerce.

by the reaction of sodium chromate or dichromate with lead nitrate or acetate. The lead nitrate is often obtained in-plant by reacting lead oxide (litharge) or pig lead with nitric acid. If zinc sulfate is to be in the pigment mixture, it is prepared by reacting zinc oxide with sulfuric acid. If lead sulfate is to be in the pigment mixture, it is formed by the addition of sodium sulfate to the reaction vessel in which lead chromate is formed. The precipitated and mixed pigment material is subsequently filtered out, treated for development of the specific pigment properties desired, and packaged.

The basic lead chromate (chrome orange), which may be described as a coprecipitate of lead hydroxide and lead chromate, is produced by the addition of lead hydroxide to the reaction vessel in which lead chromate is formed.

(4) Molybdate Chrome Orange. The pigment known as molybdate chrome orange (or molybdenum orange) is a mixed crystal of lead sulfate, lead chromate, and lead molybdate. In the production process a mixture of sodium chromate and sodium molybdate is added to a solution of lead nitrate or acetate to produce the precipitate.

(5) Zinc Yellow. Zinc yellow pigment is a complex mixture whose composition includes zinc, potassium, and chromium. Of the two types of zinc yellow, the low chloride-sulfate type is prepared by first reacting zinc oxide with potassium hydroxide, then adding the chromate as a solution of potassium tetrachromate. High chloride zinc yellow is made by reacting zinc oxide with hydrochloric acid and sodium dichromate to produce a zinc yellow slurry. The solids are removed by filtration, dried, milled, and packaged for sale.

(6) Iron Blues. Iron blues include Prussian blue, Chinese blue, bronze blue, etc. The generalized production process, which varies somewhat from plant-to-plant, involves the precipitation of ferrous sulfate-ammonium sulfate solutions with sodium ferrocyanide to produce ferrous ferrocyanide, followed by oxidation of this product to ferric ferrocyanide by sodium chlorate. The precipitated pigment is filtered, washed, dried, surface-treated to enhance pigment properties, and packed.

#### b. Producers

Producers of chrome pigments (including iron blues) together with plant locations are shown in Table 45. Interestingly, none of the producers shown in the table is integrated back to the primary raw material, sodium bichromate. Only du Pont is integrated forward to derivative products. Du Pont is a major producer of paint.

#### c. Manufacturing Economics

Estimated manufacturing costs for a chrome pigments complex are shown in Table 46. This estimate is for a hypothetical facility with

TABLE 45

## CHROME PIGMENT PRODUCERS

		Chrome Green	Chrome Oxide Green	Chrome Yellow & Orange	Molybdate Chrome Orange	Zinc Yellow	Iron Blues
American Cyanamid	Willow Island, W. Va.	✓		✓	✓		✓
Childs Pulp Colors, Inc.	Brooklyn, N.Y.			✓	✓		
Du Pont	Newport, Delaware			✓	✓		
Harshaw Chemical	Louisville, Ky. Chicago, Ill.			✓ ✓	✓		✓
Imperial Color (Hercules)	Glens Falls, N.Y.	✓	✓	✓	✓	✓	✓
Mineral Pigments Corp.	Muirkirk, Md.			✓		✓	
National Industrial Color	Chicago, Ill.			✓			
Pfizer, Inc.	Lehigh Gap, Pa.		✓				
Reichhold Chem.	Brooklyn, N.Y.			✓	✓		
The Shepherd Chem. Co.	Cincinnati, Ohio		✓				
Smith Chemical & Color	Jamaica, N.Y.		✓				



TABLE 46

ESTIMATED COST OF MANUFACTURING CHROME PIGMENTS

Investment		\$3,000,000	
Capacity		5,000 Tons/Year	
	<u>Quantity/Ton</u>	<u>\$/Unit</u>	<u>\$/Ton</u>
<u>Variable Costs</u>			
Raw Materials			
Sodium Bichromate	0.66 tons	270	178.20
Other			155.00
Utilities			
Steam	17 M lb	1.00	17.00
Process water	20 M gal	0.40	8.00
Power	335 kwh	0.0137	4.59
Total Variable Costs			362.79
<u>Semi-Variable Costs</u>			
Operating Labor	19 men/shift	\$4.31/m-h	131.00
Supervision	7 supervisors	\$15,000/yr	21.00
Maintenance	5% of Investment/yr		30.00
Labor Overhead	60% of Labor & Supervision		91.20
Total Semi-Variable Costs			273.20
<u>Fixed Costs</u>			
Plant Overhead	40% of Labor & Supervision		60.80
Depreciation	6.6% of Investment/yr		36.00
Taxes & Insurance	1.5% of Investment/yr		9.00
Total Fixed Costs			105.80
TOTAL COST OF MANUFACTURE			741.79

SOURCE: Contractor estimates.

capacity of 5,000 tons per year and a fixed investment of \$3 million. The facility is assumed to produce several of the chrome pigments, e.g., chrome yellow and orange, molybdate chrome orange, oxide green and zinc yellow.

As indicated in the table the total manufacturing costs for this plant (based on 1972 conditions) are \$742 per ton. Variable costs (raw materials, fuel, process water and power) account for approximately 46% of total plant costs. Semi-variable costs account for 37% and fixed costs account for the remaining 14%. If the average revenue per ton is assumed to be \$900, these manufacturing costs infer a gross profit of 18%.

#### 4. Prices

In Table 47, actual prices for the five chrome pigments plus iron blue as calculated using U.S. Department of Commerce data are compared with list prices taken from the Chemical Marketing Reporter. Conforming with the general pattern for inorganic pigments and chemicals, actual prices are slightly below list prices. The table also indicates that for the ten-year period shown, both list and actual prices have been in a generally increasing trend for all of the six materials.

Total 1972 shipments for the six products were 63,453 tons (using 1971 data for chrome green because 1972 data were not reported in the Department of Commerce source). Similarly the value of 1972 shipments (using 1971 data for chrome green) was \$57.408 million. Therefore the average unit value for the six products was very nearly \$905 per ton.

### I. COPPER SULFATE

#### 1. Summary

In 1972, U.S. consumption of copper sulfate totaled 36,000 tons, 12,000 tons less than in 1966 which was its peak year. Domestic consumption had been declining between 1966 and 1972 at an average rate of 5% a year. This trend was reversed in 1973 when demand from the agricultural sector increased and consumers stepped up inventory buying. The increase in 1973 over 1971 was about 20%. At a minimum, future near-term consumption of copper sulfate should hold present levels. U.S. trade is very small with less than 3,000 tons being exported.

The single major application for copper sulfate is as an agricultural fungicide where it has been losing market to organic fungicides because in general they are effective, less phytotoxic to some plants, and can be less expensive. In other applications, such as water treatment, copper sulfate also shares the market with organic compounds.

There are four major producers of copper sulfate accounting for approximately 80% of total production, and about eight other producers

TABLE 47

LIST VERSUS ACTUAL PRICES FOR CHROME PIGMENTS  
(Dollars Per Ton)

<u>Year</u>	<u>Chrome Green</u>		<u>Chrome Oxide Green</u>		<u>Chrome Yellow &amp; Orange</u>		<u>Molybdate Chrome Orange</u>		<u>Zinc Yellow</u>		<u>Iron Blue</u>	
	<u>List</u>	<u>Actual</u>	<u>List</u>	<u>Actual</u>	<u>List</u>	<u>Actual</u>	<u>List</u>	<u>Actual</u>	<u>List</u>	<u>Actual</u>	<u>List</u>	<u>Actual</u>
1963	880	774	890	879	680	615	960	1,020	NA	483	1,110	1,072
1964	920	840	915	897	720	646	1,000	900	NA	484	1,110	1,049
1965	940	866	915	890	760	678	1,040	968	NA	547	1,110	1,059
1966	940	873	915	948	760	693	1,040	941	NA	535	1,130	1,110
1967	980	906	975	954	760	689	1,040	941	NA	564	1,130	1,107
1968	1,020	950	975	956	800	704	1,060	859	NA	613	1,170	1,118
1969	1,020	927	990	952	800	710	1,090	963	NA	655	1,200	1,095
1970	1,080	860	1,000	954	850	753	1,120	998	NA	657	1,230	1,140
1971	1,120	965	1,030	979	880	780	1,190	1,043	740	700	1,260	1,239
1972	1,120	NA	1,030	1,011	940	764	1,260	1,121	780	766	1,380	1,308

SOURCE: U.S. Department of Commerce and Chemical Marketing Reporter.